EAST AFRICA HIGH COMMISSION

EAST AFRICAN AGRICULTURE
AND
FORESTRY RESEARCH ORGANIZATION

RECORD OF RESEARCH

for the period

1st January to 31st December, 1960

ANNUAL REPORT, 1960

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EAST AFRICAN AGRICULTURE
AND
FORESTRY RESEARCH ORGANIZATION
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CONTENTS

Page

THE STAFF OF THE EAST AFRICAN AGRICULTURE AND FORESTRY RESEARCH ORGANIZATION

PREFACE 1

INTRODUCTION

Changes in Staff and Organization 3
Work on Outside Committees and Conferences 4

WATER AND CROP GROWTH

Catchment Area Research. 7
Agricultural Meteorology 10
Soil Physics 12
Vegetation Studies 15
Scientific Liaison 17
Effect of Drought on Plant Behaviour 18
Leaf Temperatures 19
Plant Composition and Animal Nutrition 20

SOIL FERTILITY STUDIES

Phosphorus Transformations in Decomposing Plant Residues . 22
Pot Experiments 25
Advisory and Other Work 25
Microbiological Changes in Freshly Moistened Soil . . . 25
Analytical Division. 27
Analytical Services: Spectrochemical 27
Analytical Services: Chemical 32

SOIL AND VEGETATION SURVEYS

Vegetation–Land Use Survey of Southern Kenya . . . 34
Soil Survey 36

PLANT IMPROVEMENT AND PROTECTION

Sorghum Breeding Research Unit 39
Breeding for Bird Resistance 40
Breeding for Striga Resistance 41
Grain Studies 42
The Yield Potential of Hybrid Sorghum 43
Tetraploids and Autotetraploids 44
Introgression of Wild Sorghum Characters into Cultivated Sorghums 47
Sorghum Collection 49
Resistance of Maize to the Virus of Streak Disease . . . 49
Rust Disease of Beans 52
The Stem-Pitting Condition of Coffee 53
Abnormal Conditions of Legumes 56
The Diseases of Sugar Cane 56
Plant Nematology 57
Introduction of Plants from Overseas 64

ANIMAL HUSBANDRY DIVISION

Muguga South Farm 65
Kedong Ranch 67
Beef Cattle Unit 68
Pig Unit 71
Meat Unit 72
Biochemical Unit 75

CONTENTS

	Page
FORESTRY	
Silvicultural Research	77
Research on Softwoods	79
Short Term Tree Cropping	87
Forest Entomology	88
Pests of Established Forests and Plantations	89
Termites and Afforestation	91
HORTICULTURAL SECTION	93
EAST AFRICAN HERBARIUM	95
MISCELLANEOUS SCIENTIFIC SERVICES	
Joint E.A.A.F.R.O./E.A.V.R.O. Library	98
East African Agricultural and Forestry Journal	99
East African Plant Quarantine Station	99
LIST OF PUBLICATIONS BY THE E.A.A.F.R.O. STAFF DURING THE YEAR 1960	106

THE STAFF OF THE EAST AFRICAN AGRICULTURE AND FORESTRY RESEARCH ORGANIZATION AT THE 31st DECEMBER, 1960

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E. W. Russell, C.M.G., M.A., PH.D., F.INST.P.	*Director*
H. C. Pereira, D.SC.	*Deputy Director*

RESEARCH DIVISIONS

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H. G. Livingston, B.SC., PH.D., DIP. DAIRY HUSBANDRY	*Animal Nutritionist*
H. P. Ledger, N.D.D.	*Meat Research*
A. F. Dent, DIP. AGRIC., DIP. DAIRYING	*Farm Manager*
K. R. Southon, DIP. AGRIC. (EGERTON)	*Agricultural Assistant*
Mrs. A. E. Bazin	*Scientific Assistant*
Watson Njenga	*Laboratory Assistant*
Nelson Mwangi	*Recorder*
James G. Rimomo	*Recorder*
Jonathan Session	*Recorder*
Mayda Kapitapa	*Farm Overseer*
Duncan Mbugua	*Clerk*

CHEMISTRY:

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Mrs. C. C. Hood, B.SC.	*Scientific Assistant*
Paul Mungai	*Laboratory Assistant*

GENERAL ANALYTICAL CHEMISTRY:

G. T. Chamberlain	*Spectrochemist-in-Charge*
M. T. Friend, M.SC., A.R.I.C.	*Analytical Chemist*
A. J. Searle	*Scientific Assistant*
C. A. Spinage	*Scientific Assistant*
Leonard Nganga	*Laboratory Assistant*
Chege Mugane	*Laboratory Assistant*

ECOLOGY:

C. G. Trapnell, O.B.E., B.A.	*Ecologist*

FORESTRY:

A. L. Griffith, O.B.E., M.A., D.SC.	*Silviculturist-in-Charge*
P. Howland	*Forester*
Evanson Ndungu	*Laboratory Assistant*
Amos Wanene	*Computor*
Ernest Warari Muregi	*Forest Ranger*

FOREST ENTOMOLOGY:

W. Wilkinson, B.SC., M.I.BIOL.	*Forest Entomologist*
T. Jones, B.SC., A.R.C.S.	*Forest Entomologist*
Josephat Kamau	*Laboratory Assistant*

HORTICULTURE AND NURSERY:

W. B. May, F.R.H.S.	*Horticulturist*
Angel Gathara	*Nursery Foreman*
Ndungu Ngware	*Nurseryman*
Njorogi Karanja	*Nurseryman*

NEMATOLOGY:

A. G. Whitehead, B.SC., A.R.C.S.	*Nematologist*
Mrs. M. A. Ledger, N.D.D.	*Scientific Assistant*
Livingstone Kariuki	*Laboratory Assistant*

PHYSICS:

(H. C. Pereira, D.SC.)	*Physicist-in-Charge*
O. Kerfoot, M.A., B.SC.	*Silviculturist*
J. S. G. McCulloch, B.SC., PH.D., A.INST.P.	*Agricultural Meteorologist*
M. Dagg, B.SC., PH.D.	*Soil Physicist*
P. H. Hosegood	*Scientific Assistant*
J. A. Forsgate	*Scientific Assistant*
M. A. C. Pratt	*Scientific Assistant*
Ezekiel Kasavuli	*Senior Overseer*
Peter Ngugi Nganga	*Computer*
Edward Stephen Waweru	*Computer*
Samuel Mwanzia Kinyali	*Laboratory Assistant*
Wallace Gichuru	*Laboratory Assistant*
Jacob Mudianga	*Laboratory Assistant*
Eliud Ndungu Kago	*Laboratory Assistant*
Francis Ngugi Charles	*Observer*
Joshua Njoroge Kuria	*Observer*
David Njuguna	*Observer*

PLANT BREEDING AND GENETICS:

H. Doggett, M.A., A.I.C.T.A.	*Plant Breeder-in-Charge*
D. Jowett, B.SC., PH.D.	*Plant Breeder*
Henry Ojulong	*Recorder*
Barnabus Kifua	*Laboratory Assistant*
Charles Peter Okutui	*Recorder*
Samuel Echako	*Recorder*
Samuel Odele	*Recorder*
Michael Ogwal	*Recorder*
John Oposia	*Recorder*

PLANT PATHOLOGY:

H. H. Storey, C.M.G., M.A., PH.D., F.R.S.	*Plant Pathologist*
Miss F. M. L. Sheffield, D.SC.	*Plant Pathologist*
Mrs. A. K. Howland, B.SC.	*Scientific Assistant*
Ferdinand Wamagata	*Laboratory Assistant*
Geoffrey Kuria	*Laboratory Assistant*
James Kuria Njoroge	*Laboratory Assistant*

PLANT PHYSIOLOGY:

J. Glover, M.SC.	*Plant Physiologist*
Amos Chege Kagunyi	*Laboratory Assistant*

SOIL SURVEY:

R. M. Scott, B.SC.	*Soil Surveyor*
Stephen Kamau Nahashon	*Laboratory Assistant*

SYSTEMATIC BOTANY:

B. Verdcourt, B.SC., PH.D.	*Botanist-in-Charge of the E.A. Herbarium*
G. L. Lucas, B.SC., F.L.S.	*Botanist*
Miss D. M. Napper, B.SC.	*Scientific Assistant*
R. M. Polhill, B.A.	*Scientific Assistant*
George Williams	*Laboratory Assistant*
Edward P. K. Kaya	*Laboratory Assistant*
Petro C. Owite	*Clerk*

MISCELLANEOUS SCIENTIFIC SERVICES

JOINT E.A.A.F.R.O./E.A.V.R.O. LIBRARY:

Mrs. L. D. Verdcourt, A.L.A.	*Librarian*
Mrs. F. M. Searle	*Clerk*
Daniel Lazarus	*Assistant Librarian*
Joseph Okakah	*Bookbinder*

THE EAST AFRICAN AGRICULTURAL AND FORESTRY JOURNAL:

(J. Glover, M.SC.)	*Editor*
Mrs. K. T. Rogers	*Assistant Editor*

THE EAST AFRICAN PLANT QUARANTINE STATION:

(Miss F. M. L. Sheffield, D.SC.)	*Pathologist-in-Cahrge*
P. J. Dickinson, DIP. HORT.	*Scientific Assistant*
Peter Mwithiga	*Laboratory Assistant*

ADMINISTRATION

ADMINISTRATION AND ACCOUNTS:

Lt.-Col. G. G. Robson, P.S.C.	*Administrative Secretary*
(H. B. Hobkirk)	*Accountant, posted from Accountant General's Department*
Mrs. M. A. E. Bwye	*Personal Secretary to Director*
Mrs. M. M. May	*Personal Secretary*
Mrs. G. L. Dickinson	*Personal Secretary*
Miss A. M. West	*Personal Secretary*
Mrs. W. Griffith	*Secretary/Stenographer*
(S. I. Mascarenhas)	*Accounting Assistant, posted from Accountant General's Department*
(G. J. Oraro)	*Accounts Clerk, posted from Accountant General's Department*
Matthew N. Waweru	*Administrative Clerk*
Edward Munyua	*Clerk/Telephonist*
William K. Peter	*Clerk*

MAINTENANCE, WORKSHOPS AND STORES:

J. B. Drummond, M.I.C.W.A.	*Senior Maintenance Superintendent*
L. Boundford	*Maintenance Superintendent*
L. R. F. D'Souza	*Storekeeper*
Sher Mohamed	*Senior Foreman*
Vir Singh	*Foreman Artisan*
Noor Mohamed	*Foreman Artisan*
Soma Puna	*Senior Artisan*
Arthur Robert	*Artisan*
Ngaruiya Waweru	*Artisan*
Kamau Kangethi	*Artisan*
Muigai Njuguna	*Artisan*
Peter Kimani Mukuria	*Artisan*
Kamiti Gichuhi	*Artisan*
Mohamed Hassan	*Artisan*
Mwaura Ngabu	*Artisan*
Benson Gaitho	*Artisan*
Benson Mukumi	*Artisan*
John Kihanya	*Artisan*
Kiarie Gachohi	*Artisan*
Kiragu Ndungu	*Artisan*
Njuguna Kibe	*Artisan*
Hezron Kagone	*Artisan*
Geoffrey Mburu	*Stores Clerk*
John Ndungu	*Clerk*
Saduma Otiende	*Clerk*
Joseph N. Njoroge	*Clerk*
Simon Ngigi Kinuthia	*Clerk*
Jackton Owake	*Overseer*
Kitonga Kiarie	*Driver*
Kinyanjui Macharia	*Driver*
Muchane Wamuti	*Driver*
Wamagata Karanja	*Driver*

DEPARTURES DURING 1960

T. Graham	*Agricultural Assistant on Retirement*
J. W. Simmons	*Scientific Assistant on resignation*
Miss E. M. Boehm, B.SC.	*Scientific Assistant on resignation*

PREFACE

The East African Agriculture and Forestry Research Organization (E.A.A.F.R.O.) is an interterritorial research organization administered by and forming part of the East Africa High Commission. It was set up in 1948 and absorbed the earlier East African Agricultural Research Institute at Amani, Tanganyika, which was started in 1927. E.A.A.F.R.O. is financed jointly by the three East African Territories of Kenya, Tanganyika and Uganda, by the Protectorate of Zanzibar, and by the United Kingdom Government through Colonial Development and Welfare Funds. Its headquarters and central laboratories, experimental farm and forest plantations are in Muguga Forest near Nairobi on a site generously given by the Government of Kenya.

E.A.A.F.R.O. works very closely with the corresponding organization for veterinary research, the East African Veterinary Research Organization (E.A.V.R.O.). The two organizations have a common headquarters at Muguga, and the two sets of laboratories and farms are on adjoining estates each excised from the Muguga Forest. They are jointly responsible for the Library, which is the largest and most complete libary for agriculture and the agricultural and ancillary sciences in East Africa. In addition, research work on animal industry is shared out between them. Work on the more practical aspects of animal management and nutrition is the responsibility of the E.A.A.F.R.O. Animal Husbandry Division, whilst work on animal physiology, biochemistry and genetics is that of the E.A.V.R.O. Animal Production Division. The Muguga South Farm, which is managed by the Director, E.A.A.F.R.O., is used by both these Divisions.

The general research policy for E.A.A.F.R.O. is decided by the East African Agricultural and Fisheries Research Council, a Council whose members are nominated by the Territorial Governments, the High Commission and the Colonial Office, and this Council is also responsible for the general running of this Organization.

The principal functions of E.A.A.F.R.O. are to undertake research work that is either longer-termed than is easily undertaken by the Territorial Departments of Agriculture and Forestry, or is common to all or several of the Territories, or which requires highly specialized equipment or research officers, which can only be justified in a central East African laboratory. Examples of each of these types of work will be found in the body of this Report.

E.A.A.F.R.O., however, is only concerned with problems of local interest when specially invited by a Territorial Department. Its function is therefore to supplement and supply the background to the work of the territorial research workers.

The planning of the detailed research policy of E.A.A.F.R.O. must obviously be done in very close co-operation with the Territorial Departments, and this is ensured through three Research Co-ordinating Committees. These Committees, and others for other sciences, are under the Chairmanship of the Chief Administrative Secretary of the High Commission, and the Director E.A.A.F.R.O. is a member of each. These Committees are for Agriculture, on which are the four Territorial Directors of Agriculture; for Animal Industry, on which are the Directors of Agriculture, the Directors of Veterinary Services and the Director E.A.V.R.O.; and for Forestry on which are the Chief Conservators of Forests. These Committees, in conjunction with the Research Council, keep under review all the research work in progress and decide on general priorities for research, particularly the long-term or more specialized research that is the direct concern of E.A.A.F.R.O.

E.A.A.F.R.O. is also directly concerned with a further set of Committees, the Specialist Committees, which are composed of the actual specialist research workers in East Africa in each of the disciplines represented. These Committees are therefore competent to discuss the technical problems with which the research workers are faced in carrying out their work, and to make detailed proposals for new work or for an extension of current work.

It was decided at the 3rd Meeting of the Research Council held on 3rd February, 1955, that the Annual Reports of E.A.A.F.R.O. should be published in two parts; one part, which is contained in the Annual Report of the Research Council itself, is intended to tell the non-scientist of the work and achievements of E.A.A.F.R.O. in the year under review; the other part, which is this Report, is written more for the information of research workers, particularly in other parts of the world.

INTRODUCTION

CHANGES IN STAFF AND ORGANIZATION

Staff Changes. One new Research Officer joined the staff of E.A.A.F.R.O. during the year, G. L. Lucas, a systematic botanist who is working in the Herbarium. He was appointed last year, but spent a year working in the Kew Herbarium before joining our staff. No Research Officers left during the year, but Dr. H. C. Pereira, the Deputy Director and Head of the Physics Division has been appointed the Director of Research in the newly formed Agricultural Research Council of Rhodesia and Nyasaland. Fortunately, it has been agreed that he shall remain at E.A.A.F.R.O. until the end of May, to allow him to write up for publication most of the work he has done here. It is also very gratifying to report that at the end of this year he was awarded the degree of Doctor of Science by London University on the strength of the research work he has carried out in East Africa.

Among the Scientific Assistant staff we have lost five members, T. Graham by retirement, C. A. Spinage, who has been given a place in London University to study Zoology, K. R. Southon, J. W. Simmons and Miss E. M. Boehm by resignation. We have recruited two new Scientific Assistants J. A. Forsgate and M. A. C. Pratt, both of whom have joined the Physics Division.

We continue to lose some of our best African Laboratory Assistant staff. This year we have lost E. Kasavuli from the Physics Division, who has been appointed to the very much more senior post of Water Bailiff with the Kenya Government, and T. K. Rimi and A. W. Charles, who were both computors and who have been awarded scholarships to Universities.

Grants from Outside Foundations. It is very gratifying to report once again that we have received very generous help from outside Foundations. The Rockefeller Foundation gave us £3,000 at the beginning of the year for the purchase of a comparator-microphotometer for the Spectrochemical Division. This will increase very considerably both the accuracy and the rate at which the intensity of spectral lines on photographic plates can be read. They also gave £1,500 to help equip the Sorghum Breeding Research Division, which is stationed at the Serere Agricultural Experiment Station belonging to the Uganda Department of Agriculture. At the end of the year they gave us a further grant of over £21,000, to be available over a period of four years, to expand the work of this Division by providing additional staff and

the other facilities necessary for maintaining a really inclusive collection of sorghums there. This will be of the greatest assistance to our sorghum breeding work, and it will have the additional advantage that we will be able to co-operate more closely with the principal sorghum breeding stations in other countries.

The Nuffield Foundation have sent Dr. M. D. Gwynne to work in our Plant Physiology Division for a year and are supplying us with all the specialist equipment he is needing for his work. He is a biochemist from the Department of Botany of Oxford University, who has been working on the biochemical changes which drought can bring about in plant leaves. He will be applying his methods to the leaves of maizes which are believed to differ in their ability to withstand drought, to see how far it will be possible to develop a rapid laboratory method for comparing the drought resistance of new maize varieties. The Foundation has also given us £1,500 for the first stage of an African Intermediate School for the Muguga Estate, which will open in January, 1961. We are particularly grateful for this grant, since there are no simple ways by which a High Commission estate, such as Muguga, can find the capital needed for erecting school buildings.

Visiting Scientists. Three research scientists have spent periods of up to several months at E.A.A.F.R.O. M. J. Goode from the East Malling Research Station, started working here in December, 1959, as was noted in last year's Report and continued here for a month in 1960. Dr. Ellis Griffiths, from the University College of Wales, Aberystwyth, worked on the microbiology of the flush of decomposition of humus which occurs when a dry soil is wetted. Both these visits were paid for out of C.D. & W. funds, and we are most grateful that these funds were made available to these two workers. A. de Grisse, a nematologist from I.N.E.A.C., Belgium, spent several months working in our Nematology Division before taking up a post in the Kivu Province of the Congo. He carried out several very valuable nematode surveys in Tanganyika during this period.

WORK ON OUTSIDE COMMITTEES AND CONFERENCES

The Director is a member of the East African Agricultural, Animal Industry, and Foresty Research Co-ordinating Committees, and Chairman of the Specialist Committees for Soil Fertility, which met at Kawanda in April, for Agricultural Machinery, which met at Nakuru, also in April, and for Pasture Research. He was also a member of the Quinquennial Advisory Committee for Higher Education set up by the Governors of the three East African

Territories. He is a member of the Kenya Agricultural and Veterinary Research Advisory Committee, the Kenya Pasture Research Advisory Committee, the Research Committee of the Kenya Coffee Board, the Kenya and the Tanganyika Sisal Research Committees. He is a member of the Governing Body of the Tea Research Institute of East Africa, and Chairman of its Research Committee, and a member of the Namulonge Advisory Board of the Empire Cotton Growing Corporation. He is a member of the Scientific Council for Africa South of the Sahara (C.S.A.) and attended its 11th Meeting at Cape Town in September, and a member of he Agricultural Research Council of Rhodesia and Nyasaland.

During the year, he organized and was Chairman of a Specialist Conference on "The Control of Couch Grass, particularly with the use of Dalapon" and a more general Conference on Plant Parasitic Nematodes and their Control, which was attended by most of the nematologists of Africa and many East African plant pathologists. Mr. A. G. Whitehead, the E.A.A.F.R.O. nematologist, played a very important part in organizing and running this Conference. Further, Mr. Whitehead visited some coffee areas in Angola at the invitation of the Portuguese Government, where trees are dying from a disease whose cause has not yet been established, but which might be aggravated by nematode attack on their root systems.

Dr. H. H. Storey is a member of the E.A. Medical Research Council and the E.A. Industrial Research Board, and a Trustee of the Coryndon Museum. He is Chairman of the Specialist Committee for Agricultural Botany, which met in March at Arusha and Chairman of the E.A. Standing Technical Committee on Plant Import and Export, of which Dr. F. M. L. Sheffield is also a member and Mr. P. J. Dickinson, of the E.A. Plant Quarantine Station is the Secretary.

Dr. H. C. Pereira is the Secretary of the E.A. Catchment Area Research Committee, the Kenay Catchment Area Research Committee and the Eastern African Regional Committee for the Conservation and Utilization of Soils. He attended the 4th International Conference on Irrigation and Drainage held in Madrid in June; and he also spent three months in Israel on an F.A.O. Technical Assistance assignment on experimental methods for the study of catchment area managements. Both of these came within his period of overseas leave. Dr. J. S. G. McCulloch, also of the Physics Division, attended the meeting of the British East and Central African Territories Informal Hydrological Conference, which was held in Blantyre, Nyasaland.

Dr. W. J. A. Payne is a member of the Kenya Pasture Research Advisory Committee, and with Dr. H. G. Livingston, a member of the Research Advisory Committee of the Kenya Pig Industry Board.

Dr. A. L. Griffith is a member of the E.A. Timber Advisory Board and Chairman of the Specialist Committee on Forestry. He attended an F.A.O. Study Tour and Seminar on the conifers of Central America held in October and November.

Mr. Tecwyn Jones attended the 7th Commonwealth Entomological Conference and the 1960 Annual Convention of the British Wood Preserving Association, which was held in England, and the 11th International Congress of Entomology, held in Vienna.

WATER AND CROP GROWTH

CATCHMENT AREA RESEARCH

H. C. Pereira, J. S. G. McCulloch, O. Kerfoot, M. Dagg, P. H. Hosegood, J. Forsgate, M. Pratt, assisted by Ezekiel Kasavuli, Edward Waweru, Peter Ngugi, Samuel Kinyali, Francis Ngugi, Eliud Kago, David Njuguna, Joshua Kuria, Daniel Levi, Sabino Obol, Jacob Mudianga

The Physics Division provides the nucleus of full-time staff necessary for the conduct of the series of interdepartmental catchment area studies described in previous Annual Reports. The object is the physical analysis of the manner in which the water regime is affected by major land use changes in streamsource areas. The volume of data received each month from catchment experiments in Kenya, Uganda and Tanganyika set the Division some difficult staffing problems during the year. At one time three of the seven senior staff were on overseas leave, while all four of the Laboratory Assistants possessing School Certificates left for university education in Kenya, India, Italy and the U.S.A. respectively. Dr. Dagg returned from the United Kingdom and Mr. Forsgate joined the Division in April, Mr. Pratt joined the Division in June and Dr. Pereira returned from overseas in October, the Division thus regaining a full muster only for the last quarter of the year. Continued support from the field staffs of Forestry, Water Development and Agricultural Departments of all three Territories is gratefully acknowledged.

The energy and water balance "budgets" were completed for the main experiments and a detailed account of the method of analysis was prepared for the Inter-African Hydrology Conference to be held in Nairobi in January, 1961.

In outline the method consists of measuring solar radiation, wind-run, air temperatures and humidities, and by Penman's energy-budget methods computing the theoretical "open water" evaporation losses. Evaporation pans in contrasting exposures, both the "Class A" and the air-insulated sunken pan, are operated in order to relate the results to other stations and to longer sequences of years.

Streamflow, tabulated hourly from autographic weir records, and rainfall assessed from a network of both daily-read and autographic gauges, are compared to obtain the water loss, or apparent evapotranspiration, in a moving series of 12-month totals. The ratios between the apparent transpiration and the open water

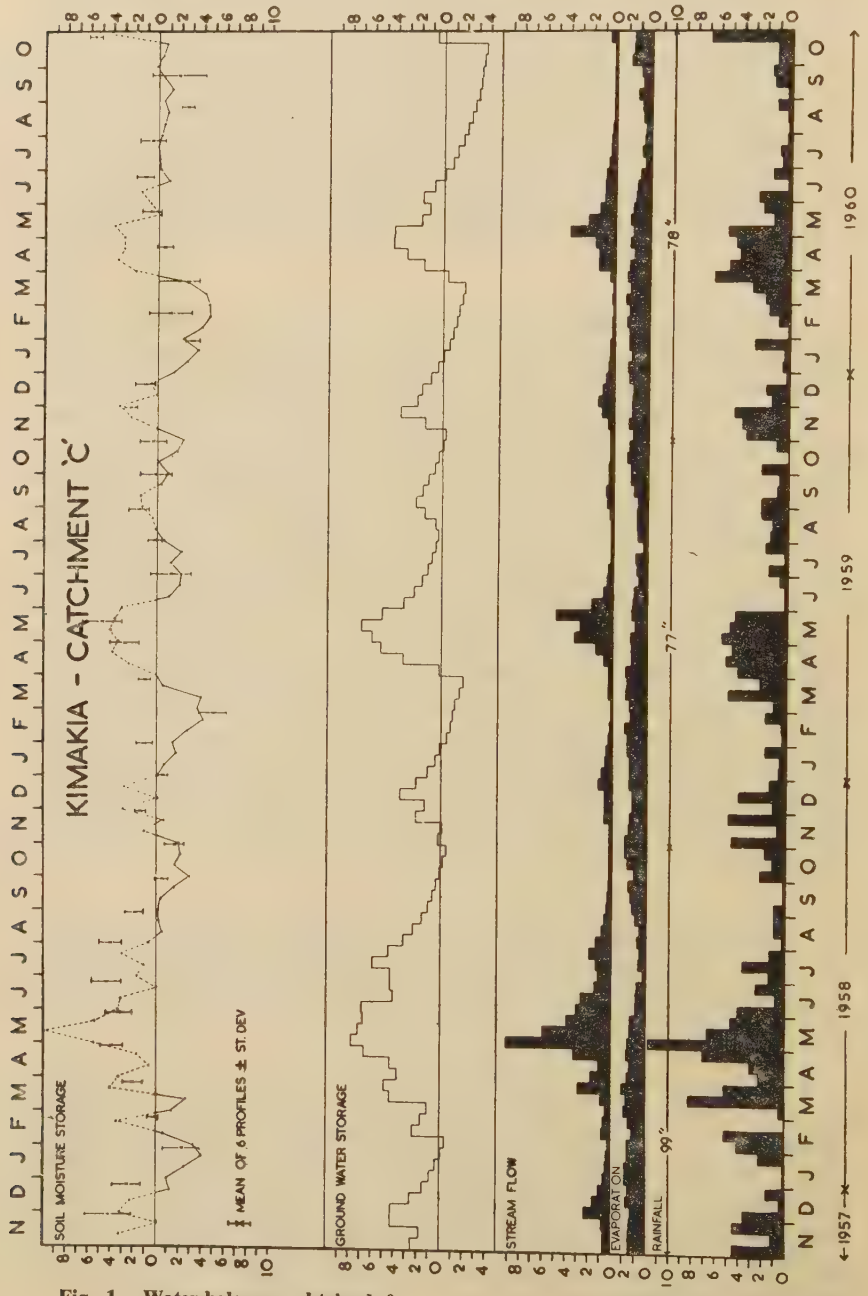

KIMAKIA - CATCHMENT 'C'
SOIL MOISTURE STORAGE
MEAN OF 6 PROFILES ± ST. DEV
GROUND WATER STORAGE
STREAM FLOW
EVAPORATION
RAINFALL
99"
77"
78"
N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
1957
1958
1959
1960

Fig. 1.—Water-balances obtained for a valley in undisturbed bamboo forest

TABLE I.—FIRST STAGES OF PINE PLANTATION IN BAMBOO FOREST

(all data in inches depth over catchment area, for Water Years 1st November to 31st October)

VALLEY A (87 acres)					VALLEY C (161 acres)					A AND C
Rainfall (ten gauges)	Stream-flow (Hourly totals)	Annual Soil Moisture Storage Change (in 10½ ft.)	Approx. Water Use	Ratio ET/EO	Rainfall (nine gauges)	Stream-flow (Hourly totals)	Annual Soil Moisture Storage Change (in 10½ ft.)	Approx. Water Use	Ratio ET/EO	Open Water Evaporation
1957–58 Vegetables and 18 inch pine seedlings					1957–58 40 ft. high Bamboo Forest					
92	66	+1	25	0·51	99	58	−2	43	0·88	49
1958–59 Maize and Pine Saplings 5–8 ft. high					1958–59 40 ft. high Bamboo Forest					
72	36	−1	37	0·72	77	31	Nil	46	0·91	51
1959–60 Patula Pine Saplings 12–15 ft. high					1959–60 40 ft. high Bamboo Forest					
74	33	+1	40	0·78	78	29	+2	47	0·92	51

The Open Water Evaporation EO is from the Penman Equation, substituting direct radiation measurements by the Gunn-Bellani Radiation Integrator, and checked by open-pan measurements. ET is the apparent annual water use.

evaporation fluctuate as a result of seasonal water storage in the catchment, but the mean values are constant from year to year in the control valleys. These mean ratios are applied to a detailed soil moisture storage computation, over successive ten-day periods: the measured field capacities and wilting points of the first ten feet of soil used in these calculations, are obtained by 1/3 atmosphere and 15-atmosphere tension measurements.

A completely independent check on the reality of these combined budgets for energy, total water and soil moisture storage is obtained by periodic soil moisture samplings to 10 feet. Some 5,000 soil samples a year are taken by African staff resident on the experiments, two-thirds are posted to Muguga for oven-drying and the remainder are oven-dried by the E.A.A.F.R.O. Senior Observer at the Tea Research Institute Laboratories at Kericho.

An independent assessment of the land-use change is obtained by separation of storm-flow from base-flow in the stream records, and then by comparing storm flow with rainfall intensity, amount and distribution, obtained from the detailed analyses of some 20 autographic rainfall records by 10-minute intervals.

Interim results over the first three years already provide factual information on the stream-regulating effects and water use of both tall rain forest and bamboo forest, and the rapid restoration, under tropical conditions, of the full ratio of water use as vegetation regrows after clear-felling. Examples of the water-balances obtained are given in Fig. 1 and in Table I for a valley in undisturbed bamboo forest. The violent runoff and shallow rainfall penetration caused by severe over-grazing in rather dry pastoral country and the soil loss from steep slopes caused by traditional methods of peasant cultivation in steep valleys have also been obtained as measurements on complete valleys.

Arrangements are in hand for the publication during 1961 of the first three years of data on all four series of experiments by an Editorial Board representing the many Departments co-operating in these studies.

AGRICULTURAL METEOROLOGY

James S. G. McCulloch and Peter Ngugi Nganga

Collection and analysis of the meteorological measurements undertaken in connexion with the Catchment Area Research Programme, and from additional meteorological outstations all over the territories continue as a routine, and enough data has now

SUMMARY OF METEOROLOGICAL OBSERVATIONS AT MUGUGA, 1960

	RAINFALL	AIR TEMPERATURE			AIR HUMIDITY			WIND SPEED	RADIATION	SUN-SHINE	OPEN WATER EVAPORATION			
		MONTHLY MEANS OF DAILY VALUES									MONTHLY TOTALS			
	Monthly Totals	Max.	Min.	Mean	Dew Point Mean of 0830 and 1600 hrs.	Saturation Deficit Mean of 0830 and 1600 hrs.	R.H. at 1600 hrs.	Mean Wind Speed at 6 ft. above ground	Kipp-Moll Solarimeter	Mean Daily Sunshine Hours	Sunken Pan Air-Insulated from Soil	Australian Pattern 3 ft. Deep Sunken Tank	Raised Pan with Light Grid Cover	Class "A" Pan
	Inches	°F	°F	°F	°F	mm. of Mercury	%	M.P.H.	Inches* Water Evaporated	Hours	Inches	Inches	Inches	Inches
Jan.	1·81	72·0	52·6	62·3	50·7	4·74	51	7·5	11·49	9·0	6·89†	6·38	7·76	8·37
Feb.	0·27	74·8	52·7	63·8	49·3	5·95	40	9·2	11·81	10·1	7·58	7·26	8·94	9·59
Mar.	5·88	72·1	54·0	63·1	53·9	4·07	54	8·0	11·30	8·3	6·97	6·61	7·68	8·15
Apr.	5·37	69·5	54·4	62·0	55·9	2·73	67	7·2	9·59	7·6	5·38	5·13	5·55	6·10
May	3·24	68·3	51·6	60·0	53·8	2·55	63	5·9	8·75	7·0	4·52	4·35	4·94	5·29
June	1·29	67·7	48·9	58·3	51·2	2·84	55	5·5	8·54	7·3	4·38	4·27	4·79	5·28
July	0·17	66·2	47·0	56·6	49·4	2·72	58	5·0	7·06	5·2	3·69	3·62	4·14	4·51
Aug.	0·60	69·0	47·3	58·2	49·8	3·25	54	5·4	7·53	5·5	4·27	4·14	4·90	5·34
Sept.	0·80	70·4	49·1	59·8	50·1	1·54	53	6·4	8·08	6·1	4·97	4·78	5·42	5·95
Oct.	2·30	71·8	51·9	61·9	50·8	4·64	48	8·8	9·65	7·1	6·18	5·92	7·15	7·62
Nov.	2·62	70·7	52·9	61·8	52·7	3·90	53	8·4	10·96	9·1	6·38	6·05	6·95	7·50
Dec.	0·89	72·1	53·0	62·5	51·3	4·77	49	10·0	11·36‡	9·4	7·21	7·06	8·36	8·71
Annual Total	25·25	—	—	—	—	—	—	—	116·12	—	68·42	65·57	76·58	82·41
Annual Average	—	70·4	51·3	60·9	51·6	3·64	54	7·3		7·6	—	—	—	—
Average Total	36·52 (10 yrs.)	—	—	—	—	—	—	—	113·83 (4 yrs.)	—	64·98 (8 yrs.)	61·21 (7 yrs.)	71·34 (8 yrs.)	83·42 (2 yrs.)
Average Mean		69·9 (8 yrs.)	51·8 (8 yrs.)	60·8 (8 yrs.)	52·1 (8 yrs.)	3·63 (8 yrs.)		7·1 (8 yrs.)		7·3 (8 yrs.)				

*1 inch water evaporated = 1,498·6 gm. cal/cm².
†Tank under repair, so evaporation estimated using regression equations for raised, gridded and Australian Pans.
‡Kipp Moll Solarimeter under repair, radiation estimated from Gunn Bellani radiometer.

accumulated to permit a more serious study of underlying relationships. In particular the study of rainfall distribution over catchment areas has necessitated application of more complex statistics than the simple random sampling usually adopted. A paper on stratified sampling of rainfall was prepared for the 1961 Inter-African Hydrology Conference. Studies of estimation of evaporation from meteorological data have continued in close collaboration with Dr. H. L. Penman of Rothamsted. Meantime the Penman equation, with the radiation term modified for use at different latitudes by Glover and McCulloch, has been used in a survey of East and Central African evaporation pan data in an endeavour to determine the underlying relationship between exposure and the performance of the various evaporation pans. An interim report was presented by Dr. McCulloch to the British East and Central African Territories Informal Hydrological Conference at Blantyre, Nyasaland, and a further report prepared for the 1961 Conference. All these studies of evaporation point to the dearth of knowledge of radiation in Africa and considerable progress has been made in calibrating and setting up Gunn-Bellani radiation integrators at a number of Government and quasi-Government stations.

Further improvements were made in the game-proof storage raingauges, with additional strengthening against theft of the containers. Additional gauges were set up in the N.F.D. by Mr. Kerfoot and in the Serengeti National Park by Dr. McCulloch and Mr. Pratt.

Extensive field inspections of meteorological and catchment equipment were undertaken during the year, and a reconnaissance visit was made to the Lembus Forest Catchment areas.

As from 1st July, Dr. McCulloch was asked to undertake the duties of Statistician at Muguga and since that date statistical advice on layout, and analysis of experiments has been provided for officers at E.A.A.F.R.O.

SOIL PHYSICS

M. Dagg, P. H. Hosegood, J. A. Forsgate and Samuel M. Kinyali

Effects of tie-ridging and contour cultivation have been further studied, using the equipment designed by Hawkins of the N.I.A.E., on four contrasting soil types. Firstly on the volcanic "Kikuyu Red Loam" at Muguga, the terracing and ley-rotation trial, described in the Annual Report for 1953 (p. 56), has completed its first six-year cycle. Twelve successive arable crops have been grown on slopes of 8 per cent to 10 per cent without terracing, by the use

of contour ridging and tying, the latter operation being by hand until this year. No soil has been lost by sheet or gully erosion, although survey by Mr. Brook of the Kenya Department of Agriculture showed that there had been a small general downhill "creep" of surface soil. The severe soil erosion often observed on this soil type has clearly been due to faulty farming practices, since when carefully farmed it has proved to be remarkably resistant to erosion. The only occasions in the past six years in which the Parshall flumes on the collecting ditches have shown heavy run-off were from good star-grass leys during intensive grazing.

The remaining three soil types are near Arusha in Tanganyika. Here a co-operative experiment by Dr. Dagg, Mr. McCartney of the Tengeru Regional Research Station and Mr. Richards of the Tanganyika Agricultural Machinery Testing Unit is studying the water relations, practical tillage and weed-control problems, and the crop yields of maize grown on the flat, on open ridges and on tied ridges. The soils, surveyed by Mr. Scott of E.A.A.F.R.O. are locally designed as "black cotton, red and grey". All are of volcanic origin with some alluvial reassortment. They comprise a dark brown calcareous clay which cracked deeply on drying, a chocolate-brown clay loam derived from tuff, which also shows some cracking in the dry season, and a grey water-laid volcanic ash. Mr. Hosegood installed gypsum resistance units, made in the Muguga laboratories, to a depth of five feet and took soil core profiles from pits for assessment of volume-weight and permeability. A junior assistant from Tengeru was trained at Muguga in electrical resistance recording, soil moisture sampling and the care of a recording rain-gauge.

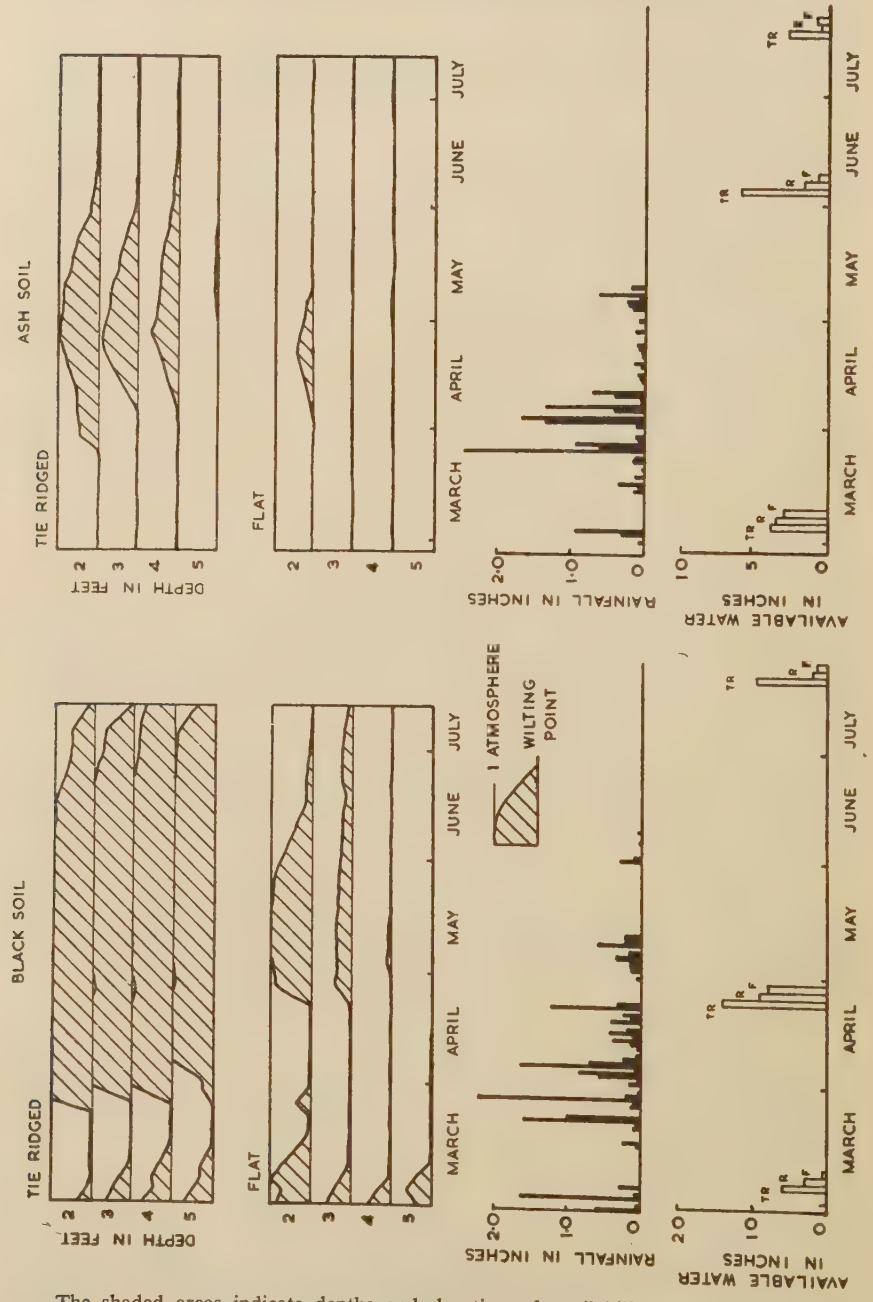
All sites are flat, with less than 1 per cent slope, but in the absence of soil conservation measures, run-off and sheet erosion are serious from the erratic 25-inch rainfall. Maize and beans alternate under continuous arable cultivation without fertilizers.

Fig. 2 illustrates the highly effective improvement in water penetration under tie-ridging, and the remarkably poor penetration of rainwater into the ash soil. The yield responses, although significant, were unexpectedly small, the tied ridges averaging 18 per cent higher than the flat with a mean yield of 13 bags (2,560 lb.) grain per acre.

Effects of Grass Roots on the Physical Structure of Subsoil

In experiments on the regeneration of "Lunyu" soil after exhaustive cotton cropping, the Uganda Department of Agriculture laid down a field trial at Kawanda Research Station to compare elephant grass and *Imperata cylindrica* ("Lusenke", or "Lalang") with continuous cropping to maize and cotton. After three years

Fig. 2.—The effect of tie-ridge cultivation with the N.I.A.E. equipment on the penetration of rainfall (soil moisture changes below the second-foot depth)



The shaded areas indicate depths and duration of availability of soil moisture to the crop, at the 2-foot depth and below. The crop, on the flat cultivation, appears to have depended mainly on the water in the first 1½ feet.

Available water was measured by soil sampling at the last inter-row cultivation, tasselling and harvest.

Note that scale for available water in Black Soil is double that for Ash Soil.

of grass rest, the experiment was core-sampled by Dr. Dagg in June, 1960. Rainfall acceptance of surface soils was measured together with percolation rates, total pore space and pore space drained at tensions of 20 cm. and 330 cm., for profiles to 3 ft. depth on all six treatments.

Unexpectedly, the structural differences were confined to the surface soil, where elephant grass burned twice per year gave significantly higher rainfall acceptance (averaging $4\frac{1}{2}$ in. per hour), total pore space and percolation rates.

In the first 3 ft. of subsoil both the grasses gave only slightly more favourable structure effects than did the continuous maize and cotton; *Imperata cylindrica* gave results a little better than those of elephant grass, but the subsoil structure effects of the various grass rests failed to reach practical importance.

Irrigation

Dr. Pereira prepared an assessment for the Kenya Joint Irrigation Committee, in March, of the water use of star grass pastures on the Perkerra Irrigation Scheme and on the probable areas which could be irrigated. After much discussion during the year, in which specialists in pastures, animal husbandry, physics, engineering and biometrics took part, an experiment on the response of pastures to watering treatments was devised. The treatments included optimum watering, using the Gunn-Bellani radiation integrator for estimation of water use, watering to halve the computed deficit, and *ad hoc* watering on the basis of the highly variable run of the river.

On bunded paddocks laid out by Mr. Hossen, Mr. Forsgate installed 20 V-notch boxes and three portable autographic float recorders, all constructed at the Muguga Workshops. Mr. Hosegood took profile sets of soil cores for volume weight measurements. The experiments are scheduled to begin in the long rains of 1961.

On the Mbarali Irrigation Scheme in Southern Tanganyika Dr. Dagg and Mr. Forsgate planned a joint experiment with the Tanganyika Agricultural Corporation and the Ilonga Regional Station of the Department of Agriculture. Mr. Forsgate levelled in and installed Parshall flumes and gates, and placed some 50 gypsum resistance blocks, in preparation for detailed crop water use studies.

VEGETATION STUDIES

O. Kerfoot and E. Mungai

Root Systems of Tea and Shade Trees

The study of the roots of tea bushes and shade trees, summarized briefly in the 1959 Annual Report aroused great

interest. This work was extended during 1960 to include the effect of spacing of tea bushes on the pattern of their root development in co-operation with the Kenya Department of Agriculture at the Kagochi Experiment Station in the Nyeri area, and to the study of root systems of large shade trees at Kericho, in co-operation with Messrs. Brooke Bonds. Root systems were studied on both Cheboswa and Kimuga Estates. Volumetric soil samples from 15-ft. deep profiles were taken to Muguga for dispersion and the estimation of the volumes of tea and shade roots respectively per cubic foot.

Visits were paid, in company with Tea Research Institute staff, to estates in the Mufindi and Usambara areas of Tanganyika to site similar studies.

Plate I illustrates one of the root systems studied at Kagochi. In continuation of observations on the soil moisture effects of tea spacing mentioned in the 1958 Annual Report, Mr. Hosegood took a series of dry-weather 10-ft. profiles in the different spacings.

Mr. Kerfoot assisted the Tsetse Control staff of the Kenya Department of Veterinary Services in the initial root studies of *Euclea divinorum* which are basic to the control of this species in the Trans Mara area.

Description of Catchment Area Vegetation

The combined work of detailed botanical description of the vegetation whose water-use is being measured, with the collection of additional material for the study by Dr. Verdcourt and his Herbarium staff of the Flora of Tropical East Africa, was continued in 1960, all experimental catchments being completed.

On the Mbeya Range the collection of 400 species included many new records for the area and several species not previously described. In the south-west Mau Forest near Kericho the Tea Research Institute staff co-operated in the collection of specimens and in the establishing of their vernacular names. Although the material is still under study by the Herbarium staff, new records have again been obtained.

In the course of a *safari* with the Kenya Forest Department staff to the Mt. Nyeru, Mathews, Ndoto and Leroghi Ranges to set up the storage raingauges already mentioned, Mr. Kerfoot collected a new member of the Cycadales (*Encephalartos* sp.).

Assistance was also given to Mr. Trapnell's ecological survey, both in the field and laboratory, and a survey of species was made on the lava and pumice area of the Kedong Ranch for the E.A.A.F.R.O. Animal Husbandry Division.

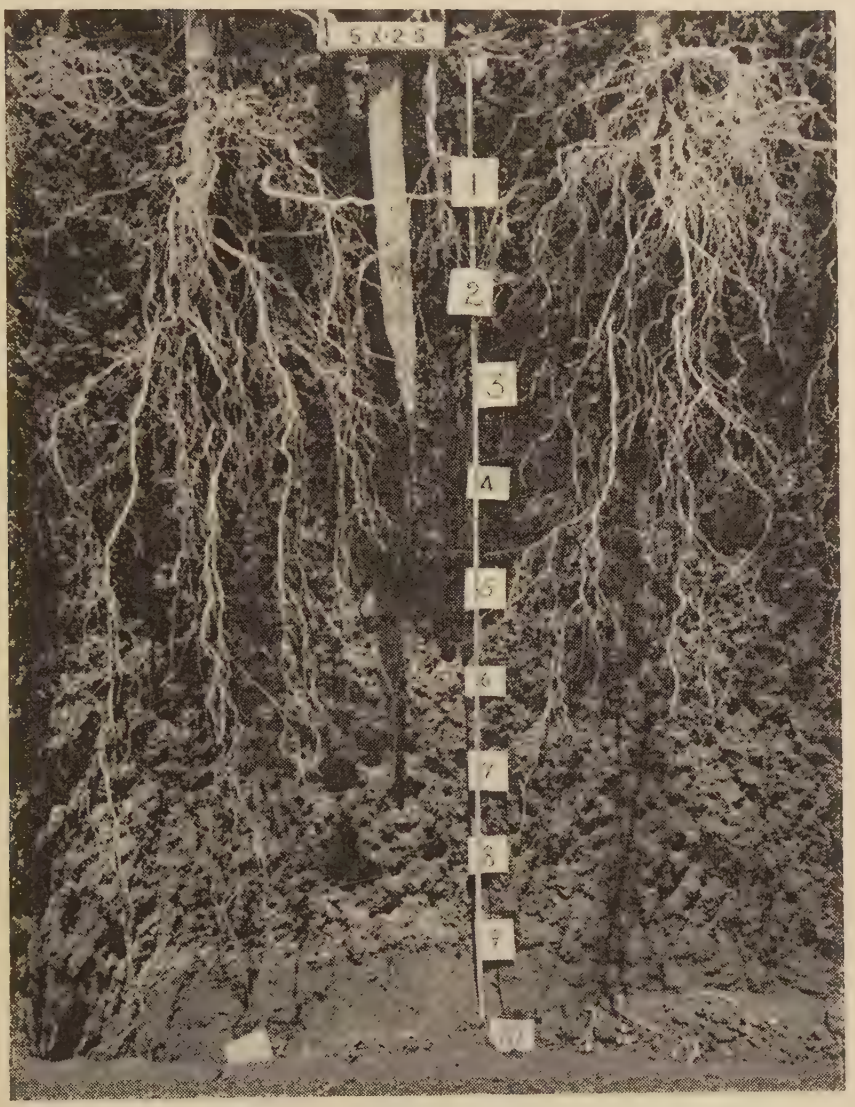


Plate 1.—Root systems of seven-year-old tea, Kagochi, near Nyeri. Planted as seedlings at 5 ft. × 2 ft. Note general absence of a tap-root and the deep vertical extension of secondary roots

SCIENTIFIC LIAISON

In February, Dr. Pereira undertook a reconnaissance of the protective forest reserves in the Ngorongoro Conservation Area and advised the Authority on policy for water conservation; Dr. Dagg addressed the Round Table in Nairobi. On overseas leave, Dr. Pereira addressed the Association of Civil Engineers in London,

attended an International Conference on Irrigation in Madrid, and visited Israel on an F.A.O. assignment to assist in a problem of research into watershed management.

Dr. McCulloch visited Blantyre, Nyasaland, and read a paper on the physics of evaporation to a meeting of the Water Engineers of the six British East and Central African Territories. Dr. Pereira addressed the Kenya Water Resources Authority at Kericho on Catchment Area Research. Mr. Kerfoot read a paper on tea root systems to the Annual Conference of the Tea Research Institute of East Africa.

EFFECT OF DROUGHT ON PLANT BEHAVIOUR

J. Glover and M. D. Gwynne

The stomatal behaviour of two millets, bulrush millet (*Pennisetum typhoideum*) and finger millet or Wimbi (*Eleusine coracana*) is being investigated. Preliminary results show that they behave in a similar manner to sorghum. The work on drought resistance was extended to studies of stomatal behaviour of some economic trees during long dry spells. The diurnal stomatal movements of *Eucalyptus saligna* and *Cedrela mexicana* were examined. Of these the Eucalyptus showed no obvious reaction to drought during a period of three months when the rainfall over the period was only $4\frac{1}{4}$ in. The stomata of this species appeared to behave normally and no obvious change in turgidity of leaf could be detected by eye, which is what one would expect from the structure of the leaf.

Cedrela mexicana on the other hand is a tree that is much less drought tolerant than the eucalypts. It reacted to drought by first showing erratic changes in stomatal behaviour of the lowermost leaves which later dried and fell off leaving only a small tuft of younger leaves near the growing point. The younger leaves did not show the erratic changes induced by the drought, and were the last to suffer severe water stress.

The programme of work with maize, which was begun in October, 1960, has for its object to find out if there is a simple, reliable test for ascertaining the degree of drought tolerance of a maize crop, and is involving a study of the growth and metabolic behaviour of maize as the water supply to the plant becomes increasingly restricted. Field trials have, therefore, been initiated using eight different maize varieties including the drought resistant maizes from Central America mentioned in last year's report, and their growth patterns recorded. These show that up to the 9th week there is no significant difference between them when grown under identical conditions. These experiments are still in progress.

Work has also started on the effect of water shortage on mature maize. This indicates that maize behaves in a manner similar to other drought-tolerant plants investigated by M. D. Gwynne (e.g. *Tradescantia warsewicziana*). The oldest leaves die off, and the materials contained in them are transported to the younger tissues and used for their maintenance. In *T. warsewicziana* these are carbohydrates, proteins and water. Studies on the carbohydrate shift in maize are at present in progress, and later this work will be extended to include proteins and the transport of amino acids. It is this research project which is being largely financed by a grant from the Nuffield Foundation.

LEAF TEMPERATURES

J. Glover

Mr. J. Goode of East Malling Research Station, England, spent some weeks continuing the work of measuring leaf temperatures which was begun last year. He examined in considerable detail the differences in temperature between different parts of the same leaf as well as between the "average" leaf temperatures and the mean temperature of the ambient air. Last year's work had been done using groundnut leaves, which have stomata on both sides, so for this year's study the leaves of *Eugenia jambolana*, which have stomata on the lower side only, were used.

Somewhat surprisingly, the records obtained from *Eugenia jambolana* leaves during the day gave very similar results to those already reported for the groundnut. Thus for the groundnut we found that [1]

$$t_d°C = -1.2 + 0.0086\,u + 3.10\,r - 0.0011e_a$$

where $t_d°C$ is the difference between leaf temperature and that of the mean ambient air, u is wind speed in metres/sec., r is incoming solar radiation in gram calories per square centimetre per minute and e_a is the evaporating power of the air, here taken as the product of wind speed (u) and saturation deficit in mm.Hg.

For *Eugenia jambolana* the corresponding relation is

$$t_d°C = 0.86 + 0.0047\,u + 2.86\,r - 0.0009e_a$$

which is very similar to that for the groundnut. However, the groundnut, which has stomata on both sides of the leaf, runs about 1° C. cooler than the *Eugenia jambolana* leaf which has stomata on one side only. It is not yet clear whether this difference is due to the difference in stomatal pattern.

[1] This formula was given incorrectly in last year's report.

Some experiments were then made with artificial "leaves" to test if this difference in leaf temperature between these two species could be due to this difference in stomatal pattern. Artificial leaves were made by sealing filter paper in a polythene sandwich. In one "leaf" the paper was wet, in another, dry. Thermocouples were inserted in each and both were similarly exposed to the sun. The wet "leaf" was consistently warmer than the dry, by about 1° C., presumably because of higher heat capacity. The polythene bottom surface of the wet "leaf" was then perforated many times by pin pricks and this caused the temperature of the wet "leaf" to fall to about that of the dry. The wet "leaf" was then perforated on both sides and this caused its temperature to be consistently about 1°C. lower than the dry "leaf".

The *Eugenia jambolana* leaf behaved like the groundnut in that on a bright windy day it is generally slightly warmer than the surrounding air but not to any great extent. Under very bright insolation of some 1.9 g.cal.cm^{-2}min^{-1}, very low wind speeds (about 1 m.p.h. or 0.5 metres per sec., and some 15 mm. Hg. of saturation deficit the leaf can be more than 5° C. above the temperature of the ambient air, but these conditions do not persist for any long period. Negative temperature differences, that is when the leaf is cooler than the surrounding air, are only found on those rare occasions when there is low radiation, moderate to high wind speeds and moderate to high saturation deficit of air. These are generally found at the onset of a local thunderstorm when the main air-stream over the plant is turbulent and dry, and the insolation is intercepted by the developing clouds.

PLANT COMPOSITION AND ANIMAL NUTRITION

J. Glover

The extension of the joint work with Dr. H. W. Dougall of the Grassland Research Station, Kitale, on the changes in plant composition which occur throughout growth, although primarily of plant physiological interest, has thrown light on the nutritive value of pastures to the ruminant, in particular to dairy cattle. The changes in the available energy and carbohydrate and crude protein contents of various Kenya pastures have been followed throughout the growing season, and we have found that the available energy of the herbage, on a dry weight basis, remains remarkably constant during the season, though its protein content drops. It has long been appreciated that dairy cows feeding on grass only cannot make full use of the protein in young grass, because its available

energy content is too low, nor of the available energy in mature grass because its protein is too low. But there seems to have been little work done on the composition of the sward needed to give most efficient production of milk, that is when its available energy and protein content can both be fully utilized.

We have been able to show that this occurs when the sward has a crude protein content between 11 and 14 per cent (1.75-2.25 per cent N) and it is substantially the same for all breeds of milking cows.

SOIL FERTILITY STUDIES

PHOSPHORUS TRANSFORMATIONS IN DECOMPOSING PLANT RESIDUES

H. F. Birch and C. C. Hood

A large proportion of the total phosphorus in East African soils is organic, so that its derivation and behaviour are of interest. Much of the organic phosphorus arises from the decomposition of plant material and it is with this aspect of the problem that we are primarily concerned. Fluctuations in the water-soluble inorganic phosphorus fraction are first being studied as this fraction has the closest bearing on changes likely to occur under field conditions.

A high percentage (about 50 to 80) of phosphorus in plant material is in the inorganic water-soluble form. Changes in this fraction during decomposition were followed by incubating various plant materials in the respirometer and periodically withdrawing samples for analysis for up to five weeks, when decomposition was almost complete. The samples were analysed for inorganic water-soluble phosphorus. The amounts of carbon and nitrogen mineralized were also determined. A three-month decomposition period is also being studied but the results are not yet available.

A feature so far common to all the samples studied is that during the early decomposition period (first 5-6 days) there is a rapid uptake of the plant inorganic phosphorus by the micro-organisms which are particularly active during this early period of their development. The inorganic phosphorus is converted to organic phosphorus compounds required for cell synthesis and metabolic processes. If during this period the cells are killed with chloroform vapour these organic compounds are rapidly hydrolysed and practically all the phosphorus is recovered in the inorganic form. This hydrolysis is due to the high enzyme activity associated with the death of a young developing microbial population.

The amount of inorganic phosphorus taken up during this early period depends on the decomposibility of the plant material and its inorganic phosphorus content, and ranges from 0.5 to 2.0 mg. per gram of material decomposed (on an air-dry basis). On about the sixth day the amount of inorganic phosphorus is at its lowest level. On further decomposition two things may happen. Either (A) there is a gradual increase in the amount of inorganic phosphorus extractable or (B) the amount remains near the minimum level.

Behaviour A is associated with the formation of 1.4 mg. or more organic phosphorus during the early decomposition period, and behaviour B with the formation of 0.8 mg. or less. With A the rate of release of inorganic phosphorus gradually falls off to a negligible rate by the 35th day, when from 50-90 per cent of the microbially-bound organic phosphorus is released in the inorganic form. This behaviour is due to microbial death with consequent enzymatic hydrolysis of the organic phosphorus compounds. With B only 10 per cent or less of the microbially bound organic phosphorus is recovered as inorganic phosphorus. Here it appears that the amount of inorganic phosphorus produced is just sufficient for, and is reutilized by, the currently active microbial population, while with A amounts in excess of these requirements are produced.

The microbial population associated with behaviour A showed a two-day lag period before decomposition occurred, while that associated with behaviour B showed no lag period. Taking the mg. of carbon mineralized during the first two days (X) as an inverse measure of the lag period, the following equations were obtained:—

$$Y_1 = -0.046X + 2 \ (r^2 = 0.702)$$

$$Y_2 = -4.272X + 122 \ (r^2 = 0.913)$$

where Y_1 = mg. of inorganic phosphorus converted to organic phosphorus during the early period of decomposition and Y_2 = the percentage recovery of this as inorganic phosphorus on further decomposition up to 35 days.

It appears from these equations that different microbial populations and/or different substrates are involved in the decomposition processes A and B. With A the lag period is followed, on the 3rd day, by a burst of microbial activity which, on the 5th or 6th day rapidly falls off, and continues at a low level. This indicates rapid substrate exhaustion followed by microbial death and release of inorganic phosphorus in excess of the requirements of the relatively inactive residual population. With B the substrate was more uniformly decomposed, so that there was no sudden exhaustion of substrate and release of inorganic phosphorus. Further evidence for the release, or otherwise, of inorganic phosphorus as a function of the kind of microbial population involved is furnished by the fact that a plant sample which showed behaviour A could, if incubated at a higher moisture level, show behaviour B, when a funga rather than a bacterial population developed.

Micro-organisms treated with chloroform vapour during the later stages of the decomposition process gave much smaller recoveries of inorganic phosphorus than those treated during the early period. It seems that as the microbial population ages and declines their enzymes decay so that on death of the cells only a partial conversion of organic to inorganic phosphorus occurs. This possible decline in enzyme activity with advancing decomposition may also be associated with the formation of less easily mineralized organic phosphorus compounds by the micro-organisms as they age.

In every instance, so far, less inorganic phosphorus has been extracted from the decomposed than the undecomposed material. While the percentage of inorganic phosphorus in the residual material may be higher than in the original (because of carbon losses through mineralization) there is, in contrast to nitrogen, no marked mineralization of plant organic phosphorus. To test the susceptibility of this fraction to microbial attack a plant sample which had been washed almost free of inorganic phosphorus, while retaining its organic phosphorus, was incubated with glucose and ammonium sulphate. On decomposition the residual small quantity of inorganic phosphorus was rapidly and completely utilized. Only when this readily available form was used up was there any mineralization of the original plant organic phosphorus compounds. It appears, therefore, that only under conditions of extreme inorganic phosphorus deficiency and high substrate availability are the plant organic phosphorus compounds mineralized. In general the amount of inorganic phosphorus in plant material appears to be sufficient for microbial needs. Further studies along these lines should show the factors governing the relative proportions of microbially-derived, and plant-derived organic phosphorus compounds in the soil, and their persistence there.

The effect of various proportions of added nitrogen and phosphorus on the stability of the organic phosphorus compounds formed by the micro-organisms is now being studied. In addition methods for stimulating the release of the microbially bound phosphorus as inorganic phosphorus are being tried out. Meanwhile the experiments so far show that there is usually no net gain of inorganic phosphorus on plant decomposition, that plant organic phosphorus undergoes no mineralization while inorganic phosphorus is present, and that the amount of carbon mineralized over the 35-day decomposition period is not related to the amount of inorganic phosphorus eventually available. In this connexion the kind of microbial population involved has to be considered as well as the nature of the substrate.

POT EXPERIMENTS

H. F. Birch and C. C. Hood

In continuation of last year's work, soils which were either (A) kept moist, (B) air-dried and then moistened, or (C) oven-dried and then moistened were planted with maize. The order of percentage nitrogen in the crop and of nitrogen uptake were C>B>A. Percentage phosphorus in the crop followed the same order. Acid-soluble and water soluble phosphorus, pH and mineral nitrogen were much higher in soil C than A and B, but plant growth was somewhat inferior due, possibly, to disturbed moisture relationships in the previously oven-dry soil.

No plant growth stimulants (hetero-auxins) could be isolated from moist, air-dry or oven-dry soils, and aqueous extracts of the soils had no beneficial effect on the growth of maize in sand supplied with mineral nutriments.

Soils kept moist for different periods showed a decrease in ammonia and nitrate nitrogen with time but this did not affect the growth of maize subsequently planted in them after different periods in the moist state. These experiments are continuing.

ADVISORY AND OTHER WORK

During the year Dr. Birch attended a meeting of the Kenya Committee inquiring into the reasons for the decline in the quality of flour from local wheats. He also worked in collaboration with Dr. Ellis Griffiths, Agricultural Botanist at the University College of Aberystwyth, during his three months stay at E.A.A.F.R.O. While on leave he gave a lecture to the staff of the Institute of Agricultural Chemistry in Zurich.

MICROBIOLOGICAL CHANGES IN FRESHLY MOISTENED SOIL

Ellis Griffiths

An examination was made of the bacterial flora which are present during the initial stages after a dry soil is wetted. The soil used was the Muguga Kikuyu red loam, and after drying and rewetting it was put in the Birch respirometer. The rate of CO_2 production and the bacterial numbers as determined by direct cell count were recorded at three-hourly intervals for a period of 36 hours, and the morphology of all the cells seen was noted. It was

found that there were two main cell types, cocci and rods which showed a marked difference in their distribution over the 36-hour period. From Fig. 3 it can be seen that a comparatively small increase in the coccoid forms occurred shortly after moistening, and then their numbers remained at a fairly steady value. The rods on the other hand showed no increase until about 12 hours after moistening when their numbers increased very rapidly to a maximum at 24 hours. Although numerically the rods do not at any time constitute more than 50 per cent of the total population, their size in comparison with the cocci is such that they must, during their brief period of growth, constitute the greater part of the active cellular material in the soil and be responsible for the rapid increase of CO_2 production and its corresponding drop after moistening. It is probable that the cocci form the autochthonous flora of the soil and the rods the zymogenous as described by Winogradsky.

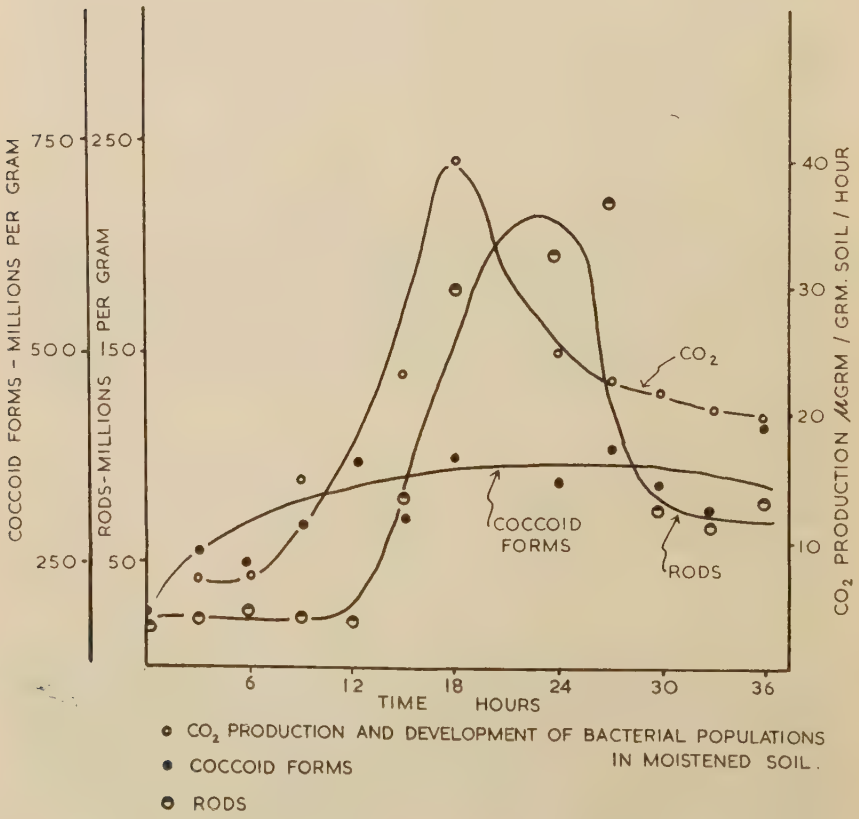


Fig. 3

ANALYTICAL DIVISION

Towards the end of 1960, the Spectrochemistry Section and the General Analytical Chemistry Section were merged to form the Analytical Division. The functions of this new Division are to carry out analytical determinations not normally carried out by Territorial departments and to provide analytical data for other E.A.A.F.R.O. Divisions. Also the Division studies the distribution of trace elements in East African soils and plants, and the merger now facilitates the determination of elements other than those determinable spectrochemically, particularly sulphur. The Division undertakes the development of improved or new analytical methods and co-operates with other laboratories in the standardization and comparison of techniques. As the merger came late in the year the work of the two original Divisions is reported separately as this represents the position for most of the year.

ANALYTICAL SERVICES: SPECTROCHEMICAL

G. T. Chamberlain, A. J. Searle, C. A. Spinage, M. D. Lamb

Requests for analyses have continued from numerous territorial departments and E.A.A.F.R.O. Divisions. After five years of this type of service, the advantages of a central laboratory for trace element analysis are becoming apparent, particularly with regard to the comparison of plant species growing in different territories.

Analyses, not including Mr. Lamb's coffee samples, during the year have totalled 121 soil extracts for bases, 367 extracts from 187 soils for trace elements, 118 plants for trace elements and eight samples of borehole water for trace elements. Mr. Lamb has analysed 142 coffee leaf samples for full trace elements, 259 for Fe and Mn only and 135 for Zn only.

To complete the calibrations of the plant ash and concentration methods, a further 132 exposures for the former and 136 exposures for the latter, were made during the year. The result of the alterations to the methods which necessitated the recalibration is that it is now possible to analyse nine samples where only six could be analysed previously. Material assistance in these developments has been received from the Rockefeller Foundation which provided $9,000 for purchasing a Jarrell-Ash comparator-microphotometer, which enables more accurate density readings from spectrograms and also a more satisfactory comparison of densities to be made. The instrument was put into commission during September.

The flame spectrographic method used hitherto for the determination of bases has now been replaced by a spark method for the determination of Ca and Mg and a flame photometric method has been adopted for Na and K. The spark method involves the soil extract being placed in a plastic funnel which is sealed on to a tungsten rod. On to the tungsten road is fitted a carbon cap which stands just proud of the rim of the funnel. A high voltage spark is passed beween this cap and a carbon counter-electrode and the soil extract is drawn into the discharge. This method results in a considerable improvement in the determination of magnesium while retaining the same accuracy for calcium determination as given by the original flame method.

Bases in Soils. All the 121 samples analysed have been in connexion with trace element investigations or soil survey investigations.

Trace Elements in Soils and Plants. A request was received from the Forest Department, Uganda for the analysis of 11 leaf samples of cypress and eucalypt, with corresponding soils (18 samples) from Awang in the West Nile district. Die-back in the cypress was causing severe loss in plantations while the eucalypts were comparatively healthy. Soil analysis revealed a very acid soil with very high available manganese in conjunction with a very low concentration of bases. The cypress foliage was found to contain <100 p.p.m. Mn while the eucalypt $>1,500$ p.p.m. Comparison with "library" analyses of the same species growing at Muguga revealed 60-100 p.p.m. in cypress foliage and 1,100-1,400 for eucalypt, when grown in a soil rich in bases. It is concluded that the cypress can be described as a mangano-phobic species, the root system of which does not permit of the uptake of more than comparatively small quantities of Mn. Hence a manganese toxicity cannot be revealed by the Mn data from foliar analysis. Similarly, it would seem that the eucalypts are mangano-philic and tolerate the high soil manganese and a high Mn concentration in their leaf. With $>1,500$ p.p.m. in the eucalypt foliage, toxicity symptoms were not observed.

Another problem encountered by the Uganda Forest Department is that of the failure of pine plantations in the Imatong Mountains. Soil analysis thus far has revealed an adequacy of the majority of nutrients with the possible exceptions of potassium and zinc. It is expected that a visit will be made to the area to collect samples of foliage for analysis. Other samples for this Department have included soils from the Moyo-Otze area of the West Nile district.

The results obtained from the cypress and eucalypt from the Awang area present a phenomenon similar to that observed at the Southern Region Research Centre, Nachingwea, Tanganyika (Annual Reports, 1957-1959). At Nachingwea, cashew and groundnuts grow well under conditions of low exchangeable bases, high acidity and high available heavy metals, in this instance, cobalt and nickel. Leaf analysis revealed high concentrations (2-10 p.p.m.) of these elements in both cashew and groundnuts. In the cases of maize and sorghum growing under identical conditions leaf analysis showed values generally less than 1 p.p.m. Co and Ni, with little if any crop being produced. It would seem that here also the toxic effect of the heavy metals is occurring at the roots and these elements do not enter to any large extent the systems of maize and sorghum. The cashew and groundnuts can tolerate considerably greater quantities of cobalt and nicket and are therefore less susceptible to heavy metal toxicity.

In continuation of the study of the trace element status of pasture in co-operation with the Animal Husbandry Division of E.A.A.F.R.O., a further 12 samples have been analysed. These samples were from the Ndeya Grazing Scheme and the Kapiti Plains, both near Nairobi, Kimakia and Eldoret, Kenya, the Moroto area of Uganda and the Northern Province Stock Farm, Tanganyika. Soil analyses from the Ndeya Grazing Scheme, which commences about three miles west of Muguga and continues to the foot of the escarpment of the Rift Valley, together with soil samples from the Kedong Ranch of the Animal Husbandry Division on the floor of the Rift Valley have, with various other samples, revealed an interesting trend in the availability of soil cobalt. Soil extracts from the Ranch using acetic acid and E.D.T.A. have all indicated 0.05 p.p.m. Co or less. Acetic acid gave 0.03-0.09 p.p.m. for the Grazing Scheme rising to 0.1 p.p.m. in Muguga. E.D.T.A. showed a marked increase in cobalt extracted as the sample sites were located progressively towards Muguga. From the values of 0.05 p.p.m. or less at the Ranch, a value of 0.2 p.p.m. was obtained from a site midway between the Ranch and the foot of the escarpment, where 1.0 p.p.m. Co was extracted. Soils of the Ndeya Grazing Scheme gave 1.5-3.0 p.p.m. and Muguga soils 4.10 p.p.m., that is up to 100 times the amount extracted by acetic acid. It is believed that this effect is due to the transition from a young volcanic ash soil in the semi-arid Rift Valley to various dilutions of ash with soil derived from Volcanic rocks combined with increased rainfall causing greater weathering as the eastern wall of the Rift Valley is ascended to enter the Central Province.

The behaviour of the soils of the Kedong Ranch towards acetic acid and E.D.T.A. represents a marked contrast to soils from areas further north in the Rift Valley, e.g. Naivasha, Elmenteita and Nakuru. Soils from these areas gave acetic acid cobalt values of 0.05 p.p.m. or less but E.D.T.A. extracted considerably more cobalt in every case, figures ranging from 0.2-3.0 p.p.m. Co.

The Forest Department, Tanganyika, requested assistance in the study of severe dieback symptoms in *Pinus radiata* growing in the Usambara Mountains. Soils and plants have been analysed and thus far no conclusive results have been obtained. There are indications that a boron deficiency might be present but this needs further investigation before a definite conclusion can be reached.

At the request of Dr. G. D. Anderson of the Northern Province Research Centre, Tengeru, Tanganyika, the Spectrochemist accompanied Dr. Anderson on a visit to various areas in the Northern Province, Tanganyika, where nutritional problems were suspected. Coffee and bean samples were collected from Monduli; coffee from Mto-wa-Mbu at the northern end of Lake Manyara; coffee, bean, pawpaw and grasses from Magard at the southern end of Lake Manyara; coffee and grass from the Mbulu area; coffee, grass and lucerne from West Kilimanjaro. In all instances corresponding soils were sampled and opportunity was taken to obtain a series of soil samples from the old lake bed of Lake Manyara to the foot of the escarpment to provide further information on the distribution of trace elements in drainage basins.

A further problem involving manganese toxicity in beans (*Phaseolus vulgaris*) was encountered by the Plant Quarantine Station, Muguga. The beans were growing in glasshouse boxes containing sterilized "Muguga Mixture" (a compounding of forest soil, peat, etc., rich in nutrients), and were divided into groups receiving the following five treatments: water only, ammonium sulphate solution, potassium chloride solution, calcium phosphate solution, and a solution containing all three nutrients. The plants receiving N and NPK treatment showed severe chlorosis while the water only treatment produced the most healthy plants. The leaves were analysed, and the Mn contents in p.p.m. in their dry matter were:—

Treatment	Water	P	K	N	NPK
Primary leaf ...	315	255	270	1900	2300
Secondary pair ...	425	255	325	2000	2700

This toxicity effect had been observed previously in sweet potato and sugar cane and it is obvious that application of ammonium sulphate to a sterilized soil mixture should be avoided.

In the Annual Report, 1959, it was noted that at the request of Professor H. Heady of the University of California School of Forestry, bases were determined in soil profiles from the Ngorongoro Crater, Tanganyika, and other areas. The Ngorongoro crater soils have now been analysed for trace elements using acetic acid and E.D.T.A. extraction. The samples ranged from near neutral soils on the slopes of the crater to highly alkaline and saline soils on the floor of the crater near the soda lake. The cobalt contents (acetic acid extraction) ranged from 0.05 p.p.m. in areas showing ash deposits to 0.8 p.p.m. at the foot of the crater. E.D.T.A. extracted considerably more cobalt, 3-10 p.p.m., from the surface and upper horizons of the profiles but frequently sharp falls to values similar to acetic acid extracts were observed at greater depths. The E.D.T.A. extractions also revealed very high molybdenum concentrations, exceeding 5 p.p.m. in the very alkaline soils, these values being among the highest recorded in this laboratory.

A further ten samples of pasture from the Veterinary Department Experiment Farm, Naivasha, Kenya, have been analysed and as no indications were obtained that the trace element content of the grass was related to milk taint, these analyses have been discontinued.

Other plant analyses carried out during the year have included plum leaf from the Kenya Department of Agriculture, coffee leaf, bean and cherry variously for the Nyasaland and Uganda Departments of Agriculture and the Microbiology Division of E.A.A.F.R.O., sisal for the Sisal Research Station, Mlingano, Tanganyika, and grasses for the Animal Health Research Centre, Uganda.

Soil extraction experiments have continued and most of the soil analyses referred to above have made a considerable contribution to the existing data on the trace element status of East African soils. A further 95 extracts using E.D.T.A. and acetic acid containing 8-hydroxyquinoline have been analysed, these being from soils already analysed using acetic acid extraction.

Kenya Coffee Analyses. The analyses carried out by Mr. Lamb will be fully reported in the Annual Report of the Coffee Research Station, Ruiru, Kenya. The samples analysed have been taken from experiments on the effect of various chelating agents (Fe, Mn and Zn) on the growth of the coffee tree and on the seasonal variation in the composition of coffee leaf. Samples have been received from Coffee Research Substations situated throughout Kenya and from estates where nutritional disorders are suspected.

Miscellaneous Analyses. Eight samples of borehole water from the Rumiruti area have been analysed for trace elements and also three samples of salt licks.

ANALYTICAL SERVICES: CHEMICAL

M. T. Friend, C. C. Hood, L. Nganga and P. Mungai

E.A.A.F.R.O. Soil Physics Section. 132 samples of silt taken from weirs in the Kimakia, Kericho and Mbeya catchment experimental areas were analysed for moisture and for organic carbon content. A further 132 soil samples from deep profiles in the Kimakia and Kericho catchment areas were analysed for coarse and fine sand, silt, clay and organic matter.

E.A.A.F.R.O. Animal Husbandry Division. Determinations of the inorganic phosphorus content of blood samples from a herd of identical twin cattle were started in September. This is part of a study of the effects of subjecting zebu cattle to the stress of infrequent watering and long daily treks; further details of this project are given elsewhere in this report. Twenty blood samples are taken at three-weekly intervals and flown here from Arusha for analysis.

Colorimetric methods for the determination of calcium in small quantities of blood serum were investigated; a method in use at the E.A.V.R.O. laboratories at Muguga was found to give reproducible results and appeared satisfactory for use under existing facilities and conditions.

E.A.A.F.R.O. Soil Survey Section. In all 70 soil samples were received from the E.A.A.F.R.O. Farm, from Nakuru, and from a traverse stretching from near Mount Kenya to the Aberdares. Analyses carried out were the estimation of coarse and fine sand, silt, clay, organic matter, nitrogen and pH.

E.A.A.F.R.O. Plant Quarantine Station, Nursery and Arboretum. A total of 35 soils were submitted for pH determinations.

Forest Departments, Kenya and Uganda. 57 soils were received for pH measurements.

Desert Locust Control. Five soil samples from Somalia were analysed for gravel, sand, silt and clay, organic carbon, nitrogen, pH, calcium carbonate and the electrical conductivity of 1 : 5 soils : water suspensions.

Plant Tissue Analysis. In connexion with the residual effects of phosphate fertilizers on the protein content of maize, 738 samples of grain and leaf grown at the Eldoret Experimental Farm were analysed for nitrogen content.

Sulphur Determinations in Soils and Plants. Further to the report on a suitable analytical method for the determination of sulphur in soils and plants (Annual Report, 1959, page 28), a start has been made on the routine determination of this important nutrient. Samples in which sulphur is being determined are those already analysed in the general study of the trace element status of East African soils and plants, and for which no reliable data on the sulphur content has been available hitherto.

SOIL AND VEGETATION SURVEYS

VEGETATION—LAND USE SURVEY OF SOUTHERN KENYA

C. G. Trapnell

This project was outlined in the last Annual Report. Its practical objective is the mapping of the complex climatic zones of Southern Kenya for land-use purposes. Its primary scientific aim is a fuller understanding of the relations of vegetation types to climate, involving a critical study of the effect of grouping meteorological data against precisely mapped vegetation zones. Major soil factors are also being taken into consideration, more particularly in the part which they play in differentiating vegetation boundaries. Very few regional studies of the climatic relations of vegetation have been attempted in Africa and it is hoped that the work will throw new light on the climatic regimes as well as on the agricultural potential of the region concerned.

The year's work has been carried out in collaboration with officers of the Directorate of Overseas Surveys, the Kenya Department of Agriculture and the Department of Veterinary Services. Mr. W. R. Birch, Pasture Research Officer of the Department of Agriculture, has been with the Survey since November, 1959, and has been concerned both with air photo interpretation and with the botanical aspects of the Survey. Mr. M. A. Brunt, Land Use Officer of the Directorate of Overseas Surveys, was originally seconded for eight months from December, 1959, but his visit was generously extended by the Directorate to a full year. He left for England on 7th December and the Survey owes a very large debt to his expert co-operation and to his guidance on cartographic questions. In addition Mr. M. Bawden from the Directorate assisted in the work of the Survey during a two-months' visit to E.A.A.F.R.O. Mr. E. C. Trump, Ecologist of the Kenya Veterinary Department, and Mr. D. B. Thomas, Pasture Research Officer of the Agricultural Department, both helped in various fields, particularly in mapping the Narok and Kajiado regions. Mr. D. J. Pratt, Pasture Research Officer of the Agricultural Department, arrived on three months' secondment to the Survey in December and participated in work in Kisii District. Mr. O. Kerfoot of the Physics Division, E.A.A.F.R.O., also contributed botanical observations in forest areas.

Mapping work has been concerned with the southern half of the region selected for survey, involving southern portions of the Central, Rift and Nyanza Provinces and the northern part of the Southern Province. The whole region had received previous ecological reconnaissance and the procedure has been to work through successive blocks of country with the aid of air photographs provided by the Directorate of Overseas Surveys. These have generally been joined up in the form of mosaics for documentation in the field. The mosaics are subsequently broken down for stereoscopic examination against alternate photographs which are being loaned by the Survey of Kenya. The boundaries determined under the stereoscope are then transposed to maps on the scale of 1 : 50,000. To date some 20,0000 square miles have been mapped by this means, representing nearly half the total area of the Survey. The rate of progress necessarily varies with the complexity or otherwise of the vegetation pattern but averages about 1,700 square miles a month.

The broad outlines of the zonal system of classification which is being employed were described in the Annual Report for 1958, which dealt with the preliminary reconnaissance. This initial vegetation study was carried out from the climax types downwards through the several phases deriving from them as a result of burning, cutting, grazing and cultivation. On the maps now being prepared climax and secondary phases are being plotted separately and in the final maps they will receive separate notation within each major zone. This means, among other things, the precise comparisons will become possible of the extent of present and inferred former forest land, while the extent of major invasions such as that of *Tarchonanthus* will appear in each zone which they have affected.

All areas of impeded drainage, including the great clay plains, are also being delimited. The role of other soil factors has become most apparent under marginal climatic conditions. That is to say that where a given zonal type of vegetation is in the middle of its climatic range it is commonly found with relatively minor variations over a range of drained soils. But near its upper and moister or lower and drier limit it may become confined to specific soils so that the exact boundary of its climatic area becomes soil-determined. The deep red earths of the Thika region, for example, have been found to carry the lowermost outliers of *Croton* vegetation projecting into the adjoining *Combretum* zone. Conversely a geologically different range of red to orange-brown soils towards Kitui carries the uppermost occurrences of dry *Acacia-Commiphora* vegetation before giving place to *Combretum*. The intervening

Combretum zone commonly attains its moister limits on shallow lava soils and its drier extremities on a sandy lateritic soil, but through the middle portion of its range extends over all of these. Only by a method of extensive survey can these varying influences of climate and soil be differentiated.

Work on the meteorological correlation will be begun in the New Year. A very large number of recording stations are involved and the Director of the East African Meteorological Services has agreed to the continued collaboration of Mr. J. F. Griffiths in this important field. His help will ensure that a full analysis of climatic data will be available for each zonal type on the maps. The final compilations of the four 1:250,000 maps projected will be undertaken by the Directorate of Overseas Surveys.

SOIL SURVEY

R. M. Scott and Stephen Kamau

Soil Surveys. The soil map of the Nairobi-Kitui-Machakos districts has been completed and it is hoped to publish this soon. The map, which consists of eight 1:50,000 sheets and covers approximately 2,346 square miles, is based on aerial photographic interpretation with road traversing.

The original project, which began in 1952, was to study the technique of air-photo interpretation of soils and was at first confined to the Nairobi-Thika-Donyo Sabuk-Athi River rectangle, which consisted of four 1:50,000 sheets. The area was chosen because it gave a variety of soils over a wide range of climatic conditions, and being situated near Muguga work could be carried on when the section was not committed to other projects. This survey was carried on intermittently until 1954 when a start was made in compiling the soil map of Kenya and Tanganyika. Over the years, requests have been made for copies of this map by the Nairobi County Council for town planning schemes and by the Hydrology Section of the Ministry of Works for their report on the irrigation potentials of the upper Athi catchment.

In view of these requests it was decided in 1958 to complete this map and to extend the area eastwards, as one large soil group had been mapped in an adjacent area by the ecology trainees under Mr. Trapnell, when they were studying a particular soil-vegetation relationship in the Yatta area. The map now covers most of the ground included in Mr. Trapnell's land use and vegetation survey of the Nairobi area and has been of value to this project.

Twenty-four different soils were recognized, mainly at world group level, for it was considered that it was no justification for separating these into series since two-thirds of the area is land used for sisal or cattle-ranching. In these areas the separation of importance is based on the drainage classes of the soils, during and after the rains.

Value and Limitations of Aerial Photographs

During the survey it was found that soil boundaries could be delineated on the photos where natural vegetation or perennial crops were present. However, in areas where annual cropping and particularly subsistent cropping were practised it was found practically impossible to interpret boundaries apart from wet lands, which were often left uncultivated. This may be due to the fact that in many cases the photos had been taken just after harvesting and therefore any soil change as reflected by vegetative growth would not be apparent.

In the main, for a particular area, different vegetation patterns and varying colour tones (which usually indicates a different vegetation type), seen on the photos, indicated differing depths and degrees of wetness of the soil. In some cases it may also indicate soils of different texture. On the other hand, the presence or absence of termite or other such mounds very often helped in separating soils of similar depth or wetness. A case in point would be between the black grumosolic soils on the Athi Plains and the adjacent vlei soils. These soils could also be separated by the presence or absence of *Acacia drepanolobium* which show up as small specks on the grumosolic soils.

It was, however, found essential to maintain adequate ground checks of the concordance between changes in vegetation and in soil type, for under some conditions a particular vegetation type would be found on a number of different soils, possibly due to influences such as fire or cultivation.

Effects of Rainfall on Percentage Saturation of the Soil

A study has been begun on the effects of rainfall on some important properties of East African soils. The first relationship examined has been that between the percentage base saturation of the soil and the mean annual rainfall for mature, well drained soils which are not derived from volcanic ash. Here the word base only includes calcium, magnesium, sodium and potassium, and the base exchange capacity was determined using ammonium acetate at pH 7. The soil samples used were taken from a depth of 3 ft. to avoid topsoil anomalies brought about by erosion and changes in vegetation.

It was found that starting with desert conditions, the soils are all fully saturated and with increasing rainfall the percentage saturation falls till it reaches about 15 per cent at about 30 in. With further increases in rainfall the percentage saturation rises once more to maximum at about 55 per cent at some 46 in. and then falls again until at 75 in. the saturation is below 10 per cent. The explanation put forward for this saturation pattern is that at the low levels of mean annual rainfall, leaching follows a simple physical pattern, but as the rainfall increases above 30 in. it becomes sufficient for much better plant growth, which leads to a more active recirculation of bases resulting in a rise of the base saturation. With further increases in rainfall above some 46 in. leaching again becomes dominant, resulting in a fall in base saturation.

Cause of Uneven Grass Growth During the Dry Season at Muguga

We were asked to investigate whether the uneven growth of star grass in some experimental plots on the Muguga South farm could be attributed to the soil. This uneven growth only became apparent during the dry season two years after it was planted. It was noted that there were mounds scattered throughout the plots and in many cases the better growth was found to be associated with these mounds but usually in patches and did not extend over the whole mound. The non-mound areas of good growth tended to be all shapes and sizes varying from small round areas about a yard in diameter to long lines of varying width. It was found when putting down holes with an auger that a tuff layer occurred at depths varying from 5 ft. to 8 ft. This tuff layer varied in thickness from less than 1 ft. to more than 3 ft. since the auger in some cases, usually in places of better growth, was able to penetrate the layer, below which a moist red soil was encountered. Chemical analysis of samples taken from good and poor growth on the mound and non-mound areas showed that the mounds had a higher pH and they contained about five times more exchangeable calcium than the non-mound area. However, there was no relationship between the growth pattern and these results and the conclusion reached was that these mounds were probably caused by termite activity.

It was concluded that the better growth was partly or wholly due to better moisture conditions, and this could be brought about by the roots being able to penetrate the tuff layer where it was thin or had been shattered by termite activity, tree roots or earth movement. This would account for the shape and size of better growth areas, and for them only becoming apparent after the second year when the roots had reached the depth of the tuff layer and been able to penetrate it where it was weakest.

PLANT IMPROVEMENT AND PROTECTION

SORGHUM BREEDING RESEARCH UNIT

H. Doggett and D. Jowett

This Division works at the Serere Experiment Station belonging to the Uganda Department of Agriculture, and we remain indebted to the Director and his staff for all the facilities they have put so freely at our disposal. The immediate general policy of this Division is to look into the possibilities of producing palatable sorghums which store well, which will suffer considerably less bird damage and give appreciably higher yields than the existing sorghums. The general lines along which the first of these problems is being tackled is to work out the genetics of a range of characters each of which is likely to decrease the attractiveness of the developing grain to birds, and then by combining together as many of these characters as possible in the same plant to test how far they reinforce each other to produce a sorghum relatively resistant to serious loss of yield due to bird damage. Arising out of this general problem work is also proceeding on the anatomy of the seed coat of sorghum grain and the inheritance of its various characters, for it is possible that by combining together a group of these characters not yet found in any one sorghum variety, losses from birds can again be reduced without loss of palatability.

The second major aspect of the work, concerning the possibility of breeding sorghums giving an appreciably higher yield than existing varieties, is involving a study of the yield potential of "hybrid sorghum" produced in other countries on the one hand, and the possibility of obtaining a hybrid autotetraploid which will maintain the yield increment due to hybrid vigour for a much longer period than do the normal diploid hybrids.

These programmes of work can only be successfully carried out if we can maintain as large as possible a collection of sorghums from all over the world having as wide a range of characters likely to be relevant to our problems. It is to help us maintain such a collection that the Rockefeller Foundation have very kindly made us a grant of over £21,000, payable over a period of four years, to set up such a collection, maintain it properly and provide a plant breeder to work through the materials so collected.

The growth of the sorghums last year was good both for the early and the late rains crops, as the rainfall was good for the early and very good for the late rains. Some trouble was caused by

Sphacelia sorghi in the first rains, but birds gave little trouble after mid-June, and neither Central Shoot Fly nor Stem Borer troubled the second crop, which was sprayed with dieldrin.

Breeding for Bird Resistance

One line of approach is to obtain a sorghum with very long glumes and we are examining the segregating types being produced from the cross 56 × 53. A line has been withdrawn from this cross which has a mean glume length in F_5 of 11.67 ± 0.61 mm. It is interesting to note that a similar line drawn from Feki Mustakke (SB217), the only long glume variety which has contributed to 56 × 53, has a mean glume length of only 10.35 ± 0.39 mm. The difference between these two lines is significant at the 0.1 per cent level. Clearly transgressive segregation has occurred in the 56 × 53 material. The awns in this material are up to 13 mm. long. Grain quality is fair to good, and many lines show the involute glume character making for easy threshing.

The second line of approach is to obtain a sorghum with a long awn. BL_2B1KO is such a cross with a mean awn length in F_7 of 17.9 ± 0.51 mm., and awns of up to 20.9 mm. were observed. However, the grain quality of this cross is disappointing.

In Table 1 the glume length of parental plants in 1959 are compared with their progeny row mean in 1960, and similarly for awn length in the BC_2B1KO material. In spite of the generally lower figures shown for glume length this year, and higher figures for awn length, there is an indication that the parents with larger glumes and awns have produced the best progenies. This indicates that advances have been made due to last year's selection. That further advances are possible, particularly for glume length, is indicated by the high standard error of the 56 × 53 line to which reference has previously been made (S.E. = 0.286 mm.) compared with the Feki Mustakke selection (S.E. = 0.185 mm.).

TABLE 1

COMPARISON OF PARENTS AND PROGENIES FOR GLUME AND AWN LENGTH

56 x 53	Glume Length	BC_2B1K0	Awn Length
Parent (F_3)	Progeny (F_4)	Parent (F_6)	Progeny (F_7)
14·8	11·5	16·3	19·0
13·8	12·0	15·3	18·0
13·0	11·5	15·2	19·0
11·1	10·6	14·7	17·1
11·0	10·6	12·7	16·6
10·0	9·5		
9·1	9·6		

The third line of approach is to produce a variety with a consistent goose-neck, and fourthly the curved stem character of Korgi is being exploited.

Crosses this year have been aimed at introducing a longer awn and above all a goose-neck or Korgi habit into 56 × 53 lines while retaining the glume size. The best goose-neck types with or without long glumes from Doggett's segregating material, and Korgi, have been crossed on to 56 × 53. In addition two new goose-necked varieties, SB 229 and SB 230, have been crossed on to several lines including 56 × 53.

The major disadvantage of 56 × 53 is the poor plant characteristics shown. A sister cross, 56 × 25, shows much better characteristics, including an excellent grain, but lacks the large glumes. Several crosses have been made from lines of this cross to 56 × 53. Crosses have also been made between 56 × 53 and Nunaba, a West African variety which is cleistogamous. A cleistogamous large glumed type might have value in resisting pests and diseases attacking the floret and developing grain.

Studies on the genetic basis of large glumes and long awns have been initiated. F_1s between SB 217 and large glumes and R_2 with small glumes and between BC_2B1KO with long awns and R_2 with short awns have been produced and grown successfully. The F_1 plants are clearly intermediate for these characters. F_2 seed is now available and F_3 families will be produced in the greenhouse during the dry season to enable trials suitable for biometrical analysis of these characters to be grown in the first rains of 1961. Two awnless African varieties, L17 and KA_4, were crossed with an African long-awn type, BC_2B1KO (mean awn length 17.9 ± 0.51) and an Indian long-awn type, IS 2639 (mean awn length 12.23 ± 0.55). All the F_1's were awned, indicating the awned condition to be dominant. The mean awn lengths were KA_4 × BC_2B1KO 4.05 ± 0.58, L 17 × BC_2B1KO 3.38 ± 0.51. The cross L 17 × IS 2639 failed, but in the case of KA_4 × IS 2639 the awns although present were too short to measure, normally not appearing beyond the glume.

Among this year's accessions to the collection, particular interest from the point of view of bird resistance attaches to the wild *Sorghum aethiopicum*. This species, although small and grass-like, has very long awns, the mean length in unselected material being 20.89 ±1.51. It is cross-fertile with cultivated types.

Striga Resistance

The perfecting of the technique for obtaining consistent results in the germination of Striga seed in the laboratory has occupied

some time. Precise control of moisture around the seed during pretreatment and germination is necessary, and contamination of the stimulant solution with fertilizer (Knopp's solution) inhibits germination. This aspect is receiving further study.

It seems clear that the Striga resistance of Dobbs observed in the field in Tanganyika is due to a reduced capacity to germinate Striga seed, presumably owing to lower production of the stimulant. The following figures illustrate this:—

	Percentage germination of Striga Seed	Arcsine
Wiru (Tanganyika local, susceptible)	28·4	32·0
Dobbs (originally from Kenya)	11·9	19·5
Framida. (Striga resistant, from S. Africa) ..	6·7	14·8
L.S.D. (P=0·05)		5·6

Selections taken from Dobbs for Striga resistance in the field have been tested, and some appear to have a greater resistance than Dobbs, but more data are required.

Grain Studies

Investigations have been carried out on the anatomy of the seed coat of 60 sorghum varieties, covering a range of types. A considerable amount of variation has been found in the structure and pigmentation of the seed coat. In particular the hypodermis may be absent or up to three cell layers thick; the epidermal and hypodermal cell walls may be heavily thickened or only slightly so; the cuticle may be thin or thick; the mesocarp, consisting of starch packed parenchyma cells, may be from 15 to 125 μ thick; the integument may be present or absent in the mature seed, and when present is always dark brown in colour, possibly due to the presence of tannins. The epidermis/hypodermis may also be pigmented, and this pigmentation varies in colour and intensity and is independent of that in the integument.

Dark-brown grain types with highly corneous endosperm do not appear to occur. Such a variety may be of great value as a bird resistant type with good storing quality, especially if milling methods to remove the bitter seed coat become available. Four varieties covering the range of colour and endosperm type available have been crossed reciprocally in all combinations to investigate the genetics of these characters and if any lines appear promising to carry them on under selection.

Chemical analyses have been made on several varieties from the collection by Mr. R. Breedon of the Uganda Veterinary Department, Entebbe. On the whole the values for crude protein tend to be considerably higher than for maize or millet. Thus the crude protein content of a group of sorghums varied between 9 and 13.7 per cent, whereas the maize grown at Serere had one of 8.2 per cent and the millet grown at Serere had one of 6 per cent.

Palatable sorghums are usually of the corneous type. 743 lines from various inter-crosses of corneous grain types developed during the Tanganyika breeding programme have been grown out. The object of this is to select the best combinations of corneous grain and yield for use as parent lines in later stages of our work. 129 selections were taken for further testing next season.

The Yield Potential of Hybrid Sorghum

A variety trial was laid down in the first rains in which 17 hybrid sorghums from Israel and seven hybrids from the United States were compared with American and good local varieties. The Israel showed up well for out of the 20 top entries 18 were hybrids, of which 14 came from Israel. Some of the results are given in Table 2:—

TABLE 2

YIELD OF SOME HYBRID AND LOCAL SORGHUMS

Israel Hybrids			U.S.A. Hybrids			Varieties		
No.		*lb./acre*	*No.*		*lb./acre*	*No.*		*lb./acre*
7	722	1,460	29	H11 x 51	580	6	CK 60	720
21	91803	1,120	19	H11 x 65	500	15	Caprock	520
26	726	1,100	2	H11 x 71	490	13	L.28	480
12	727	1,080	3	H11 x 41	480	1	Martin	400
17	724	940	14	H11 x 61	460	9	Westland	400
31	706	900	23	630	360	34	Midland	380

On a Duncan multiple range test, Nos. 7, 21, 26 and 12 are better than CK 60, and these, together with 17 and 31, are better than Caprock. The variety L.28 is a good local type, which in two timely plantings on the main farm yielded at 1,300 and 1,600 lb./acre of threshed grain, so the trial results must be accepted with caution. Nonetheless, there is an interesting indication of a marked benefit from some of the hybrids, those from Israel being of the same maturity length as L.28.

Heterosis may have a big contribution to make to African sorghum yields if we can surmount the practical problems involved in the distribution of hybrid seed to a people farming at subsistence level. Tetraploids appear to be the only possible answer to this problem at present.

Tetraploids and Autotetraploids

The object of developing tetraploid cultivated sorghums is to exploit the yield increase obtainable from heterosis. This has proved to give a 20 to 25 per cent increase of yield in the U.S.A., with greater benefits under less favourable conditions. The two initial problems are (*a*) to confirm that the inheritance of seed set follows the usual patterns of gene controlled characters, (*b*) to determine whether high seed sets can be obtained on autotetraploid varieties. Good progress has been made this season towards the solution of these problems.

Autotetraploid Cross 4NX5

This cross was made in 1956 between a BC2 Wiru line 23B/5 and a BC2 Msumbiji line 38. A large F_7 generation was grown out this year, together with remnant seed of the F_4 to F_6 generations. Selection has been practised for high seed set since the F_3. The original seed set was 30 per cent for both parents, and the mean F_1 seed set was 65 per cent and 68 per cent in two plantings. The mean F_7 seed sets of families from F_5 selections are given in Table 3:—

TABLE 3

SEED SET IN SOME AUTOTETRAPLOID SORGHUMS

F_5 Selection	F_7 Mean (percentage)	F_7 Arcsine	0·05% confidence limits
26/10/2	66·8	54·9	±0·5
26/10/4	68·9	56·4	±0·5
26/6/2	72·5	58·6	±0·6
34/12/1	69·6	56·6	±1·2
39/37/1	71·5	58·0	±0·8
3/8/1	69·5	56·7	±1·2
9/3/2	75·3	60·7	±1·0

Grouped as F_6 families, the F_7 lines give means ranging from 63.4 per cent (52.9 ± 1.1) to 75.6 per cent (61.2 ± 1.4). The F_7 line means themselves range from 59 per cent to 78.9 per cent, but with an average of only seven plants counted per row, the confidence limits are not given. Transformation and analysis of the data is not yet completed, but it is already clear that the F_2 variance was much higher than that of the F_1 and that selection from the F_3 onwards resulted in a rapid fall in variance. Selection appears to have stabilized the seed set at around the 70 per cent level. These results would be consistent with the view that seed set is gene controlled, and is affected by selection in the expected fashion.

S. almum Crosses

S. almum is a natural tetraploid which arose in South America during the first half of this century. One of its parents was the ancient tetraploid *S. halepense*.

The only material available was a bulk received from a South African seedsman, which showed a seed set ranging from 59 per cent to 97 per cent, with the mode at 93 per cent. It was heterozygous for seed set, and high seed set lines are being selected from it. A natural cross occurred between it and the autotetraploid 23B/5 line. (There is no doubt about the origin, as *S. almum* was the only tetraploid wild type sorghum in the field, and the two rows were adjacent. The hybrids appeared in the following generation of the 23B/5.) Figure 4 shows the distribution of percentage seed set in the parents, F_1 and F_2 generation. The 23B/5 parent was not grown in the same year, as the planting proved to be almost entirely almum hybrids, but the figures give an indication of the order of seed set of this parent.

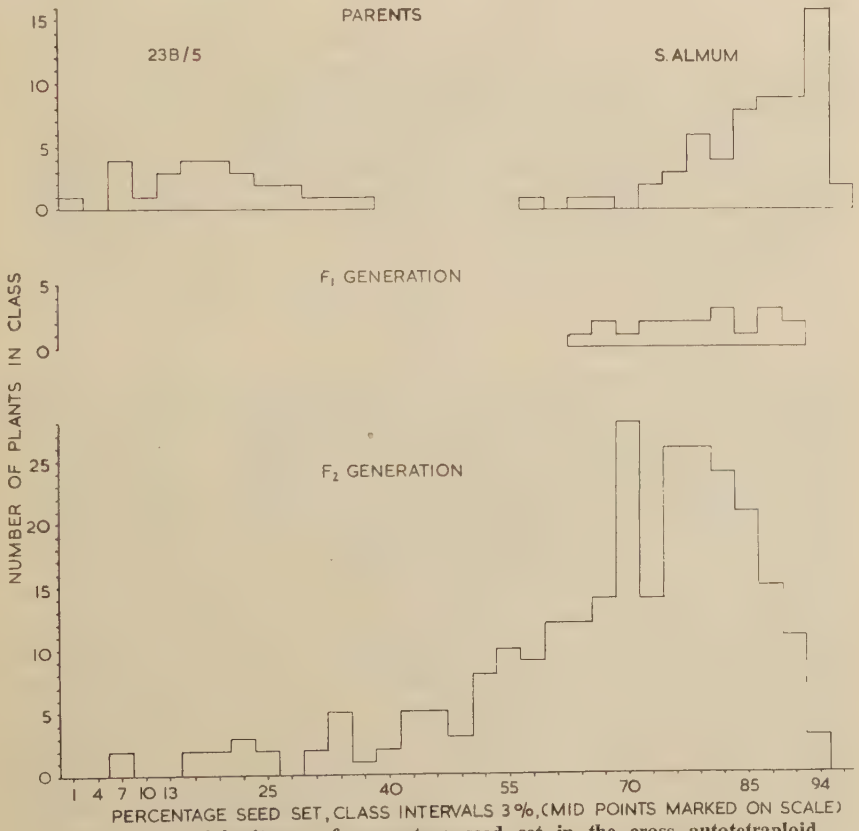


Fig. 4.—The inheritance of percentage seed set in the cross autotetraploid 23/B5 × *S. almum*.

The diagram shows that the behaviour of seed set in this cross is again what would be expected of a gene controlled character, high seed set being at least partially dominant. We may presume that *S. almum* obtained its own good seed set from *S. halepense*, and it is clearly able to transmit this character to its offspring. The

fact that one or both of the parents in this cross was heterozygous for seed set is shown by the F_2. That derived from F_1 plants with a seed set of 80 per cent or more showed a mean of 76.8 per cent (59.9 ± 1.1), while that from F_1 plants with 70-79 per cent seed set showed a mean of 60.8 per cent (51.5 ± 2.5). The figures have been combined in the diagram.

Selected heads from the F_2 of the cross (4NX5 derivatives) × *S. almum* were grown as F_3 progeny rows. Taking the F_3 as a whole, of 596 plants counted 224 (38 per cent) were in the 81-90 per cent seed set class, and 47 (8 per cent) were in the 91-98 per cent seed set class. The means of the 60 rows (15 plants counted per row) varied from 64.6 per cent to 87.6 per cent. Variances have not yet been calculated, but ranges vary from (31.1-81.2 per cent) to (72.3-96.6 per cent). There was no evidence of any very tight linkage between high seed set and wild-type almum characters as far as grain and threshing are concerned. Several plants classified as cultivated type on these characters had seed sets of 90 per cent or above, while many of the typical wild almum type plants were in the lower seed-set classes. There is every reason to believe that cultivated tetraploid sorghums with seed sets around the diploid level will be readily obtained.

Fifty-four crosses from F_2 and F_3 plants of the above were made successfully to cultivated autotetraploid sorghums.

New Autotetraploids

A range of material covering different geographical areas and different varieties or subspecies was treated with colchicine, 126 varieties in all. Tetraploid plants were identified in 79 of these. The variations in seed set are of interest, though they are based on very few plants, as only a proportion of those treated produce tetraploid shoots. Some figures are given in Table 4:—

TABLE 4

SEED SET IN SOME NEW AUTOTETRAPLOIDS

Variety	Seed Set	Range	Number of Plants
L28	80	78·5–80·3	3
Chi 91	58	44·7–69·6	6
N1	38	20·0–61·9	4
SÂ2	58	38·3–75·2	6
B5	39	32·0–48·0	5
Martin	55	49·1–62·6	3
T32	70	62·4–79·2	5
Redland	57	34·0–68·9	7
Sakwa	72	68·2–77·3	3
Wiru	55	48·0–63·7	4

These results will be confirmed next season, but it seems clear that there are differences in the seed set when diploid varieties are doubled. The original 23B/5 autotetraploid showed a mean seed set of 31 per cent and 19 per cent in two seasons recorded. A sister line 42B, doubled last year, has shown a mean seed set of 54.6 per cent (range 36.2-78.5, 37 plants counted). It seems certain that such differences in seed set must be due ultimately to gene action, and it looks as though genes affecting tetraploid seed set are distributed in the diploid sorghum population. Confirmation of this is necessary, but it is of interest from the evolutionary viewpoint, as an autotetraploid with a constitution like L28 would start with a satisfactory fertility level. L28 is a Lango local sorghum, which has been in existence for many years. The chromosome sets must be identical by now.

Summary

The data in the preceding paragraphs show that it should be possible to obtain cultivated tetraploid sorghums with stable, high seed sets without much difficulty. The inheritance picture needs properly studying by a diallele cross as soon as selfed lines are available, but the search for satisfactory combinations of tetraploid types for a study of the behaviour of heterosis can be commenced next season.

Introgression of Wild Sorghum Characters into Cultivated Sorghums

A study was made by a Makere student during the Long Vacation of the introgression of wild sorghum characters into the local cultivated varieties. Natural crosses between the indigenous wild sorghum *S. verticilliflorum* and the cultivated are frequently found at Serere and have been seen in northern and eastern Uganda, but the range of hybrid types found is very limited. But when the natural crosses are grown out and tended on Serere, a much wider range of intermediate forms occurs. There is no evidence of any barrier to the cross, the seed germinates well, and plant mortality is low. It must be presumed that many of the intermediates produced can survive under cultivation, but the majority would be weeded out by the grower unless their leaves were of the cultivated type. Most of the intermediate types cannot survive under wild conditions, or the range observed would be much greater, and *S. verticilliflorum* would be far more variable than it in fact is.

A *S. verticilliflorum* plant collected in northern Uganda yielded a number of hybrid plants when grown out. The F_2 from these segregated as three plants with sessile spikelets that shed to one with persistent spikelets (319 : 105). Leaf breadth, height and number of panicle nodes showed normal distributions with single

peaks. The non-shedding plants were grown out, and a number produced types which would be acceptable in cultivation, including some with white corneous grains, and with panicles very much resembling the Kabii and Godo types of northern Uganda. Deliberate crosses have been made this season between three lines of *S. verticilliflorum* and three cultivated types to follow what is happening. There is good reason to suppose that gene movement between the wild and cultivated types does occur in both directions, but the nature of the barrier which permits *S. verticilliflorum* to exist as a distinct type alongside the cultivated sorghums is of interest.

In the introgression study, a number of single plant collections of wild and cultivated types made in northern Uganda were grown out as head rows, together with some lines from the Western Province, and some natural hybrids. A large number of characters were measured and scored. The following of these characters were chosen, being scored finally from 0-2, and then summed for each varietal row: waxy bloom on sheath, leaf margin flat or wavy, leaf width, stem thickness, panicle length, panicle branch length, awn length, pedicelled spikelet length, seed breadth, seed length. A diagram is given in Figure 5. Each large square represents a variety, the numbers being the row numbers, W indicating wild sorghum, H wild × cultivated hybrid, and C a cultivated variety.

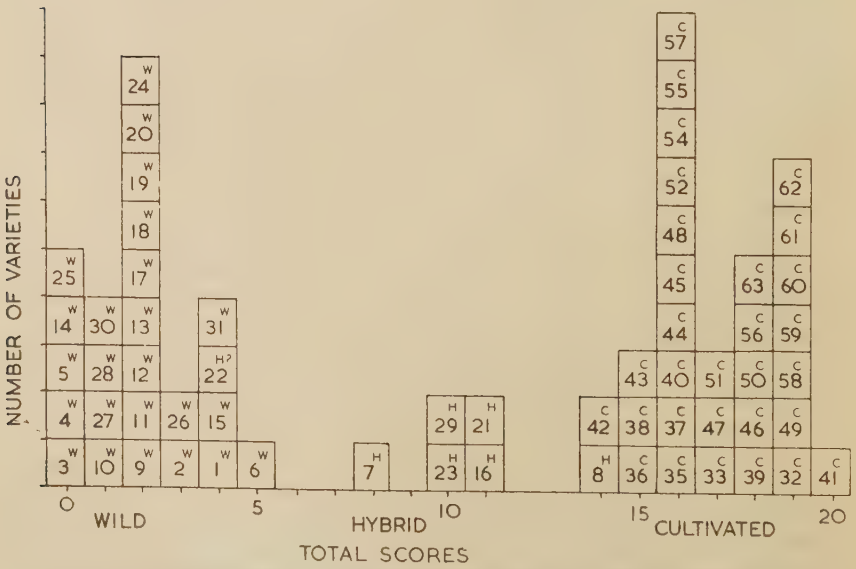


Fig. 5.—Character scores on introgression study of wild, cultivated, and wild × cultivated hybrids in sorghum

It will be seen that the wild and cultivated types fall into clearly separate groups, though there is quite a range in each. The hybrids are intermediate, except for Nos. 8 and 22. No. 8 was definitely a hybrid, No. 22 was collected as a natural hybrid but may not have been one. No. 42, in the same class as No. 8, is a Kabii from Kitgum. No. 43 is another Kabii from Kitgum, 36 is an Ijio from Teregu, and 38 is Eji Kamuri from Pakella. Nos. 57-63 are all from the Western Province, and tend to occupy the upper end of the scale. No. 41 is an Ondu from Arua. There would seem to be a possibility that the varieties in classes 14-16 could have arisen by the hybridization of extreme cultivated types such as No. 41 with *S. verticilliflorum*, followed by back-crossing to the cultivated types. Equally, the wild types in classes 3-5 could have arisen by intercrossing of class 0 types with cultivated varieties, followed by back-crossing to the wild type.

No. 21 is a sorghum sent into us by the Assistant Agricultural Officer, Moyo, Mr. Lumbwa, which he states never occurs on new land but always appears after sorghum has been grown for two or three seasons. It shows every evidence of being a wild × cultivated cross, but there is little variability in it, although some segregation for height and panicle density has occurred among its progeny.

The Sorghum Collection

Four hundred and sixteen new accessions were grown, the majority coming from U.S.A. collections, the only other large group being from South Africa. Several were of interest. Grohoma from the U.S.A. and Pietersbury Baker from South Africa via the U.S.A. yielded very well. One introduction had scented grains, and the drought-resistant kaffir crosses from Mr. Sieglinger at Stillwater, Oklahoma, may be useful. Other material of Mr. Sieglinger's which will be of great interest to us is *S. propinqum* and various crosses from it. In the main collection, 320 types were grown and observations taken. The breeding material grown totalled 2,495 head rows.

Twenty requests for seed from many parts of the world were met, of which three were for grain weevil-resistant types.

RESISTANCE IN MAIZE TO THE VIRUS OF STREAK DISEASE

H. H. Storey and A. K. Howland

For our genetical studies of resistance in maize the year has been mainly one devoted to expanding and confirming the evidence briefly reviewed in our 1959 report. The genetic picture still remains

not clearly defined. We hope during the course of 1961 to assemble our data for publication with the best interpretation that we are able to reach.

For the interpretation of our data it is becoming evident that more information is needed on certain aspects of the fundamental problem of virus infection in the maize plant. It has long been known that with this disease the virus, at least in a form or a concentration that can cause a feeding vector to become infective, is confined to the chlorotic areas of a diseased leaf. Possessing, as we now do, maize lines in which the chlorotic areas cover only a minute fraction of the total leaf area, we have been able to test this supposed localization of the virus in material different from any previously used. The outcome was to confirm, as was to be expected, that the vector cannot take up any virus effectively from the fully green areas of a leaf, although it can do so from even minute chlorotic areas.

When maize plants from a resistant line are tested by our standard routine technique—by feeding two infective *Cicadulina mbila* for two days on the first leaf of each seedling—no visible effect may result, or the seedling may produce one, or several, or a considerable number of chlorotic streaks on leaves subsequently formed. At first we supposed that these several reactions might be attributed to variations in the genetic make-up of the plants, but inbreeding of selected phenotypes appears not to alter significantly the distribution of the observed phenotypes in the families of successive generations. Inbreeding has not been carried far enough to allow of a firm conclusion on this point; but the present evidence has caused us to question whether the variations observed may not be related to variations in the amount of inoculum introduced by the vectors. We have thus considered it desirable to determine whether the number of vectors used during the infection period can influence the plant's reaction. An elaborate experiment to test this is in progress. For it, the possession of resistant maize lines believed to be genetically pure was essential, since it has long been known that even a short feed by a single insect can produce the full disease in a susceptible maize.

Another matter calling for study was the possible influence of environment on the reactions of resistant maize lines. Uniform infection tests have been in progress at two-monthly intervals and will be completed in 1961. These therefore will cover the full range of environments in which our routine testing has been done.

We have previously reported attempts to decide whether a range of streak virus races occurred in the field; if this were so, breeding for resistance against the race we maintain in our glasshouses might fail to give satisfactory field resistance. The evidence

is mounting that this is not a serious danger. It is true that one of our collections (from the Northern Province of Tanganyika) appeared at first to be slightly more virulent to some of our inbred resistant maize lines; but on subsequent passage this isolate lost any enhanced virulence, if indeed it had possessed any. In confirmation of our experimental evidence we have the general evidence that the resistant maize lines developed in the Union (from which ours derived) are evidently resistant to the streak virus occurring there; and that in field tests of our resistant lines in the Sabi Valley of Southern Rhodesia (arranged by Dr. G. R. Bates) and at Newala in southern Tanganyika (by the Department of Agriculture) these lines showed uniformly high resistance and no breakdown to the prevalent virus.

On the practical problem of streak control, we have already reported that, under the relatively exact conditions of our glasshouse experiment, the first cross between a resistant and a susceptible line can give plants that appear to tolerate the virus and to yield satisfactory crops. In 1960 we followed up this preliminary observation by comparative trials in our glasshouses. Symptom expression in the F1 plants—judged by the frequency of the chlorotic streaks on the leaves—tended to be intermediate; in early growth the difference from the susceptible parent was not very marked, but the F1 plants showed a greater tendency to recover, that is, for the streaking to become more sparse on the later formed leaves. Throughout, the F1 plants that had been infected as young seedlings yielded less than plants of the same families that had not been infected; but the depression in yield was small. In the susceptible parents similarly treated virus infection reduced yields to a fraction of that of the healthy plants.

These experiments have given a fairly exact picture of the effects of virus infection although they were only made on a small scale. Field experiments in South Africa by officers of the Empire Cotton Growing Corporation at Barberton, and later by the Union Department of Agriculture, had already shown that crosses between resistant and susceptible lines were capable of yielding well under conditions of heavy streak infection. Recently the Union Department has put this finding to practical use, by the issue to growers of seed from selected three-way crosses. (G. J. M. A. Gorter, 1959, *Euphytica, 8,* 3, 234-240.) The extensive breeding programme involved in this work has evidently led to an important advance in the practical control of streak disease. Its main value will be realized in a country such as the Union, where organization exists for the production and annual distribution of hybrid maize seed.

It could have value in East Africa up to a point; but later generations may be expected to segregate widely in respect of their streak-resistance, and consequently open-pollinated crops derived originally from F1 hybrids would lose much of their value. From an East African standpoint, it still seems worth while to continue the attempt to isolate lines carrying a complement of the genes from the adapted susceptible maize and also the resistance genes from the resistant parent.

RUST DISEASE OF BEANS
(*Phaseolus vulgaris L.*)

H. H. Storey and A. K. Howland

Not only is the bean an important food crop throughout most of East Africa but, in the Northern Province of Tanganyika in particular, a valuable export industry has been established over recent years. This industry has primarily been devoted to the highly specialized production of seed for planting, of a quality and varietal purity acceptable to overseas seed merchants. A secondary enterprise has been an attempt to enter the trade in white haricot beans for the canning industry.

Bean rust (*Uromyces phaseoli*) is present generally throughout East Africa, but the majority of varieties grown—including those on which the above bean seed industry is based—are reasonably resistant and rust has caused no particular concern. On the other hand, the white haricots hitherto grown have been liable to damage or total loss through rust attack, not only in the Northern Province of Tanganyika but elsewhere in Tanganyika and Kenya. If suitable white haricot varieties could be found or developed that were resistant to rust a useful export industry might emerge.

E.A.A.F.R.O. was invited to undertake investigations in collaboration with the Tanganyika Department of Agriculture. Our part was to apply the intensive methods of greenhouse studies, while field trials were to be done initially at the Regional Research Centre, Tengeru, near Arusha.

Thirty physiologic races of *Uromyces phaseoli* have been recognized in the United States of America and others elsewhere. It was therefore of first importance to study the diversity and reactions of the races prevalent in East Africa. We were fortunate to be able to obtain from the U.S. Department of Agriculture, Beltsville, a set of six differential bean varieties that had been used by Dr. Zaumeyer and colleagues for recognizing rust races in U.S.A. First trials were with a rust prevalent in the Muguga District; the differential bean varieties gave satisfactory reactions which characterized the race as different from any described in U.S.A.

Our next finding was that rust isolates from a number of sites in the Ausha area, collected by Mr. Clinton and Mr. Macartney of Tengeru, gave reactions on each of the differentials similar to those of the Muguga race, and were consequently believed to be identical with this Muguga race. However, a number of isolates from the Moshi area gave a different set of reactions. Up to the present, therefore, we have recognized two races only. Through the assistance of departmental officers we are extending the area of collection and hope in time to determine the races prevalent generally in East Africa. It is hardly to be expected that others additional to the two already recognized will not appear; but it is at least satisfactory that in the important export production area the prevalent races are at present restricted to two.

We had collected from organizations in East Africa samples of a wide range of beans, both coloured and white. Among the coloured were a number resistant to Race 1, but the majority of these have not been tested. The white haricots, possibly suitable for the canning trade, were mostly susceptible to rust.

Meanwhile Mr. Macartney had assembled a very large collection of white haricots from many world sources. Some of these were resistant in his field trials, and the best have been tested at Muguga. We have found that seven lines are resistant to both races of rust and among them are several that Mr. Macartney finds to have the qualities required by the canners.

The present position is, therefore, that, mainly through Mr. Macartney's work, selection among existing lines of beans has given material likely to resist rust in Tanganyika Northern Province provided no changes occur in rust races prevalent there. Conceivably a permanent solution may have been found for that area and even for other areas in East Africa, although this may be unduly optimistic. If the selected lines break down, we may be forced into breeding from crosses. This we are prepared to do if the necessity arises; but breeding would be a long-term project and no early success in securing resistance, together with the exacting requirements of the canners, could be expected.

THE STEM-PITTING CONDITION IN COFFEE

F. M. L. Sheffield

Pockets of abnormal cells are produced in the wood tissue of many young *arabica* coffee trees. As a result the wood cylinder may become pitted or furrowed on the exterior and corresponding pegs and ridges be produced inside the bark. The abnormality is usually confined to the base of the trunk which may swell. It is occasionally found in tall rapidly growing suckers which become

brittle and tend to break if carrying a heavy crop. In cuttings taken from affected trees, then rooted and kept for about 2½ years in the glasshouse until stem bases were up to 2 in. in diameter, disorganized tissue occurred only as in normal healthy trees. (*See* below.)

During the last two years several experiments have been initiated to determine whether or not the condition is due to virus infection. Most of these experiments were made by grafting scions from affected trees to healthy seedlings of several *arabica* selections raised in the glasshouses. Equal numbers of control seedlings were grafted with scions from healthy seedlings. All plants were kept under glass for at least six months after grafting. They were then put into the field as far as possible from other coffee trees, some being planted out at Muguga and others at the Irrigation Research Station at Mwea/Tebere. (Should the cause be a virus and should accidental spread occur after planting out, the latter should be shown by the relative positions of abnormal tissue in the earlier and the later infected plants.) Attempts to transmit the stem-pitting condition included the following:—

1. Approach grafts were made between healthy seedlings and rooted cuttings taken from affected trees at Lyamungu. When the union was complete, the cutting was severed below the graft. The grafted plants, the cuttings that provided the scions and the controls are now growing at Mwea/Tebere.

2. Scions from affected trees at Lyamungu were top-cleft grafted to healthy seedlings. These with their controls are now growing at Mwea/Tebere.

3. Experiment as in 2 except that the affected scions came from the grounds of the Scott Agricultural Laboratories and the experiment is now planted out at Muguga.

4. Bench grafts were made of roots from affected trees growing at the Scott Laboratories to healthy seedlings. These plants are still retained under glass.

5. (*a*) Healthy scions from seedlings raised under glass were top-cleft grafted to an affected tree at the Scott Agricultural Laboratories. Controls were scions cut from the tree and returned to it. (By analogy with virus diseases causing similar symptoms in *Citrus* spp., the stem might be expected to become pitted just above the graft union, if the coffee condition is due to virus infection.)

(*b*) Similar grafts were made to rooted cuttings from affected trees. These are now growing at Mwea/Tebere.

6. Top-cleft grafts using scions from certain abnormal seedlings from the Kisii nurseries were made to healthy seedlings which were later planted out at Mwea/Tebere. It had

been suggested that these abnormalities arose from the same cause as stem-pitting. (Many of the scions ceased to show any abnormality as soon as they were established on a healthy root stock. Similar abnormalities have now been produced in the glasshouse by faulty cultural methods.)

All these plants have now been growing in the field for a year or more. Growth at Muguga is slow but at Mwea is very rapid. All plants look healthy and there are no obvious external differences between any experimental plant and its control. So far, very few plants have been taken up for sectioning and microscopic examination for abnormalities in the woody tissue. No differences have yet been found between the members of any pair.

It is now known that disorganization of the woody tissues similar to that resulting in the stem-pitting condition can arise in coffee from several causes. It occurs naturally in the field and has been produced experimentally.

Such disorganization has often been found in the field just below the cap of multiple stem-trees. It has now been produced experimentally by capping healthy seedlings and keeping them in the glasshouse away from all possibility of infection with a pathogen.

Similar disorganization is produced near the union if a healthy scion is grafted to a healthy seedling. (This result would invalidate any that might have been expected from experiments 5 (*a*) and (*b*) above.)

Small pockets of abnormal tissue arise naturally in healthy stems near the vascular strand passing into a branch.

It is also formed after wounding. The first regeneration tissue after hail damage is of this type and it has been experimentally induced by pricking with needles, by slashing or scraping with a knife as well as by surrounding the stem with rotting vegetable material. Even the slight damage caused by the feeding of a scale insect will cause two or three abnormal cells to arise in the wood.

However, except by capping or grafting, I have not been successful in causing the continuous production of abnormal tissue. In all other cases, only a small pocket of abnormal tissue is formed before the cambium resumes its normal function.

Because this tissue can be produced in many ways, we cannot assume it will not arise as a result of virus infection: to know this we must await the result of the transmission experiments. It does, however, prove that all stem-pitting does not derive from a single cause.

ABNORMAL CONDITIONS OF LEGUMES

F. M. L. Sheffield and A. K. Howland

Lucerne

It was thought that the stunting of many plants in the museum plots at Muguga might be due to virus infection. To test whether this was so, cuttings were taken from 20 plants of several varieties and showing varying degrees of stunting: these were planted in soil in a glasshouse. Seedlings were grown and four healthy clones were built up. Some 300 grafts were made in an attempt to transmit the symptoms from the rooted cuttings to the healthy clonal material but all results were negative.

In the meantime the cuttings brought from the museum grew into apparently healthy plants. It seems likely that the symptoms in the field are due to unfavourable environment, particularly to prolonged drought, rather than to a pathogen.

Clover

Plants showing witches broom and phyllody symptoms at Kitale were brought in and planted in the glasshouses at Muguga. They rapidly grew into large, apparently healthy plants. It therefore seems unlikely that the condition was due to virus infection.

Beans

Haricot and soya beans showing virus-like symptoms have been brought in from the field. An attempt is being made to perpetuate the conditions in the glasshouse until sufficient staff are available to study the many problems involved.

THE DISEASES OF SUGAR CANE

F. M. L. Sheffield

Work on ratoon-stunting disease ceased early this year. In an attempt to find a rapid diagnostic method about two dozen different species, mostly monocotyledons, had been inoculated with extracts from infected sugar cane but none had shown either external or microscopically visible symptoms. In view of the very slight hope of success and the pressure of other problems it was decided to abandon this work.

In connexion with the occurrence of diseases in the field, I visited several estates in the Eastern Province of Tanganyika including that now being developed by the Kilombero Sugar Company and I also visited an estate on the Kenya Coast.

As a member of the Standing Committee for Sugar Cane Diseases of the International Society of Sugar Cane Technologists I have assisted in the preparation of a new World List of Sugar Cane Diseases to be published by this organization.

PLANT NEMATOLOGY

A. G. Whitehead and M. A. Ledger

Mrs. M. A. Ledger was transferred to the Division as Assistant Nematologist in May, to replace Miss E. M. Boehm who resigned in January. Valuable technical assistance has been rendered by Mr. L. Kariuki throughout the year. The eight glasshouses, soil laboratory and potting shed, generously given the Division by the Rockefeller Foundation, were erected at Muguga and are now in full use. Two further laboratory assistants joined the Division to assist in the glasshouse programme.

At the request of Professor Van Den Brande, Rijkslandbouwhogeschool, Ghent, Mr. A. De Grisse worked in our laboratories for five months. He obtained field experience by assisting with a Turkish tobacco survey in Western Province, Tanganyika, and a coffee survey on Kilimanjaro and West Usambara Mountains and described a new species of *Meloidogyne* found on Kikuyu grass roots. He left in November for Kivu Province of the Congo. Dr. J. S. Aráujo, Institute of Scientific Investigation, Luanda, spent a short period in these laboratories learning generic diagnosis of plant-parasitic nematodes for continuation of a study of *morte subito* disease of robusta coffee in Angola.

A very interesting and successful Inter-African Plant Nematology Conference took place from 24th to 28th October at Muguga. Delegates attended from Angola, Congo, Central African Federation, Ivory Coast, Kenya, Nigeria, Tanganyika, Uganda, Union of South Africa and the United States. Twenty-three papers were read.

The Nematologist assisted in the planning of a large scale root-knot nematode survey to be carried out by the Scott Agricultural Laboratories, Nairobi, in Kenya. A Nematology Training Scheme for the field staff involved in the survey will be held early next year and Uganda will also be sending personnel for instruction in field survey and laboratory techniques.

Nematode Problems of East African Crops

This year particular emphasis has been placed on intensive root-knot nematode surveys, which enable the species of *Meloidogyne* affecting a crop or area to be adequately identified. Then control measures can be worked out under glass at Muguga and in the field in experimental plots and subsequently applied.

Tobacco

Virginia Tobacco

An intensive survey of the root-knot nematode attacks of virginia tobacco farms in Iringa District, Tanganyika, was carried out in March. 50 per cent of the farms were visited and sampled. All but three were affected by root-knot. The overall crop loss in Iringa District is estimated at not less than 30 per cent. Extent of field attacks appeared to be related to soil texture, i.e. the sandier the soil the more extensive the attacks. But with prolonged tobacco monoculture very heavy attacks can be found on even fairly heavy soils. The extent of field attacks was not obviously related to altitude and rainfall.

Meloidogyne javanica and *M. incognita,* its subspecies and varieties, were the principal root-knot nematodes in tobacco fields (99 per cent of all individuals identified). The distribution of *Meloidogyne spp.* was not obviously related to the rainfall, altitude or soil texture. However, while some farms or farm blocks had a rich root-knot nematode fauna others had a relatively poor fauna. This fact is demonstrated in Table 1 and will greatly assist the application of rotational measures of nematode control in these specific farm areas.

Evidence that the species encountered may be composed of a number of biologically distinct "races", i.e. with potentially differing host ranges, is being investigated further. The occurrence of more than one root-knot nematode species on a single root system is common on Iringa tobacco farms.

Twenty-six root-knot nematode populations selected over the morphological range of the species found in Iringa farms have been successfully propagated from single egg masses on tomato plants (variety Moneymaker). They are being used to test the susceptibilities of cultivars suitable for rotation with tobacco in the Iringa District and for a study of the morphological ranges of single root-knot nematode populations.

Turkish Tobacco

Some 40 experimental plots of Turkish tobacco were established by the Department of Agriculture, Tanganyika, in 1960 over a wide area in Northern, Central, Western and Southern Highlands Provinces. The Nematology Division has co-operated in a survey of the root-knot nematode attacks of the mature plants. It has been found that nearly every plot is already infested with species of *Meloidogyne* and damage is therefore anticipated when the cultivation of the crop is extended to the surrounding districts. The species of *Meloidogyne* involved are in course of identification.

TABLE I.—DISTRIBUTION OF *MELOIDOGYNE* SPP. IN IRINGA DISTRICT TOBACCO FARMS, MARCH, 1960

Meloidogyne spp.	Nzihe	Mbeya Road	Dodoma Road	Lutemwa Road	Pawaga Road	Dabaga Road	Kilosa Road	Totals
M. javanica	976	1,209	868	438	645	241	914	5,291
M. ? *javanica*	—	11	—	—	16	—	1	28
M. incognita	—	23	37	—	9	—	39	108
M. incognita sub. spp.	—	—	90	—	—	—	12	102
M. incognita var. *acrita*	—	72	238	4	56	—	64	434
M. ? *hapla*	—	—	—	—	1	1	—	2
M. spp.	—	—	2	6	17	—	1	26
TOTALS	976	1,315	1,235	448	744	242	1,031	5,991

Indigenous Host Plants

The roots of the indigenous flora in three areas, each 50 ft. × 50 ft., selected at random in part of the Suluti area of Songea District, Southern Province, Tanganyika, were examined for root-knot nematode attack. The object of the investigation was to determine whether the indigenous flora in this hitherto uncultivated area was already attacked by root-knot nematodes, in view of its proposed use as a tobacco area. Although some 400 root systems were examined no obvious symptoms of root-knot nematode attack were found, nor were any root-knot larvae released from check root incubations. This is remarkable in view of the considerable evidence of root-knot nematode attack in indigenous flora elsewhere.

Coffee

Arabica Coffee

A survey of root-knot nematode attacks of *arabica* coffee was carried out in August on Kilimanjaro and the West Usambara Mountains in Tanganyika. The object of the survey was to determine the frequency, intensity and distribution of root-knot nematode attacks in nursery and mature coffee in these areas and to identify the species of *Meloidogyne* responsible. Root samples were examined from the topsoil of 20, randomly selected trees at each of 60 sites on Kilimanjaro and 14 sites in the West Usambaras. Similarly six nurseries at Kilimanjaro and eight in the West Usambaras were examined for infestations. The distribution of infestations was erratic. 51 per cent and 58 per cent respectively of coffee trees on Kilimanjaro and the West Usambaras were affected. 80 per cent of coffee trees were attacked at the upper end of the coffee belt on Kilimanjaro. 10 per cent of nursery plants examined were attacked in both coffee areas. Many wild plants growing in association with the coffee trees were found to harbour root-knot infestations. In addition root-lesion nematodes (*Pratylenchus* spp.) were discovered in mature coffee trees at a number of sites on Kilimanjaro. The species of *Meloidogyne* present in the coffee roots samples are being identified and at present at least two species can be recognized, one related to *M. africana* (Whitehead, 1959), the other apparently undescribed. Wild hosts carry a diverse root-knot nematode fauna, including *M. hapla* and *M. javanica,* which occur very rarely if at all on coffee roots. Investigations on root-knot disease of coffee are to be continued with the kind co-operation of the Coffee Research Station, Lyamungu.

Robusta Coffee

At the request of the Coffee Board of Angola a visit was paid to parts of Angola in May to study *morte subito* (sudden death)

disease of robusta coffee. This disease affects hundreds of acres and is spreading each year. Areas once afflicted cannot be successfully re-established at present. The disease, which causes annual losses of around £1 million sterling, is thought to be caused by a species of *Fusarium* and the object of the visit was to investigate the possible predisposition of the tree to the disease by nematode attacks. The conclusion reached in these studies was that an obvious relationship did not exist but further investigations are being undertaken by Dr. J. S. Aráujo for the Coffee Board. Root-stock resistance of some *Coffea* spp. to root-knot nematode attack was discovered in experimental plots at the Amboim Coffee Experimental Station.

Banana

A study of the potential inter-relationship of nematode root disease and Banana Wilt disease was started at the request of the Uganda Department of Agriculture. Banana Wilt has been discovered in several Districts, though most damage is caused in Ankole District, where it was first identified in Uganda. Plant-parasitic nematodes are of common occurrence in Wilt-affected banana gardens, both within the roots and in the surrounding soil. Root-lesion disease was found on all varieties examined and *Pratylenchus* spp. were almost invariably associated with the lesions. Where *Pratylenchus* spp. were absent other plant-parasitic nematodes present may have been responsible for the lesions or P*ratylenchus* spp. may have evacuated the roots. To test the hypothesis that nematode attack may increase the susceptibility of a banana plant to Wilt disease two experiments are envisaged. One is the large-scale pot test for which spore inocula of the fungus are being prepared. The other is a field trial involving soil fumigation and the testing of nematode-free stocks. To produce nematode-free stocks two techniques were investigated:—

(1) *Peeling Suckers.* This technique was found very satisfactory in Jamaica (Loos and Loos, 1960). The corm and the base of the pseudostem are thoroughly cleaned and peeled to remove infested corm tissue and roots. The peeled suckers are soaked in fungicide (0.1 per cent mercuric chloride solution used in this case) washed in water and dried in the sun. In this experiment the cut surfaces of the suckers were rubbed with charcoal to absorb sap and planted in sterile vermiculite. Four weeks later the cut surfaces were well suberized and new roots free from nematode attack were pushing through. Though the method appeared satisfactory the state of the cut superficial corm tissue was no indication of the condition of the inner tissue and on cutting open many of the corms were found to have a central soft brown rot.

(2) *Rooting "Peepers".* A more promising technique was worked out with the Horticulturist, E.A.A.F.R.O. In this the new shoots are cut off just before the formation of roots or if some roots were present in front of the rooted zone. The cut surface and the rest of the shoot were scrubbed and cut clean and dipped in a suspension of derris and a fungistatic compound (Tulisan). The cut end of this "peeper" was rubbed in Serradix rooting hortomone (three strengths were tested) and placed on the top of sterile soil in pots. After one month very good rooting was obtained compared with controls in which no rooting was observed. This method will be further tested on a larger scale.

Pyrethrum

A survey for root-lesion and root-knot nematode attacks on pyrethrum was carried out on five farms in Njombe District, Tanganyika, by the Agricultural Officer (Pyrethrum), Mr. D. F. Osborn. Examination of the material at E.A.A.F.R.O. showed only trace infection of root-lesion nematodes (*Pratylenchus* sp.) and one farm only was badly affected by root-knot nematodes (*Meloidogyne hapla*).

Aphelenchoides ritzema-bosi (Chrysanthemum leaf eelworm) has been found in diseased basal shoots of pyrethrum in western Meru, Northern Province, Tanganyika, and in aborted flowers at Bahati, Kenya, This nematode may be widespread in East African pyrethrum because typical leaf lesions are not necessarily produced on pyrethrum so that the damage may be confused with that due to other pathogens.

Taxonomic Studies of Meloidogyne *spp.*

In collaboration with Dr. M. T. Franklin of Rothamsted Experimental Station a full taxonomic investigation of the genus *Meloidogyne* has been started. A collection of type material kindly sent by Dr. A. L. Taylor of U.S.D.A., Beltsville, is being studied and, with the permission of the Standing Committee on Plant Import and Export, a collection of living exotic populations of *Meloidogyne* spp. has been started under strict quarantine at Muguga. The collection will be used both in this taxonomic study and for comparison with East African populations.

A. De Grisse has described a new species of *Meloidogyne* attacking the roots of Kikuyu grass (*Pennesetum clandestinum* Hockst.) at Muguga. It has now been recovered from indigenous forest soil at Muguga in which Cowpeas (*Vigna* sp.) were grown. The host range of this species is being tested under glass.

Control of Meloidogyne javanica

In pot tests at Muguga *Tagetes minuta* L. (Mexican marigold) was found to possess a very high degree of resistance, if not immunity, to *M. javanica,* the commonest species of root-knot nematode in East Africa. The action of the weed on the soil population was not due to a fumigation effect of root secretions. Tomato plants following a three-month growth of Mexican marigold in artificially infested soil remained free from attack by *M. javanica,* whereas controls were heavily galled. The very high degree of control obtained warrants further investigation of the susceptibilities of *Tagetes* spp. to *Meloidogyne* spp. on a large scale.

Root-knot Nematode Surveys of Cultivated Areas of East Africa

The first of a series of intensive local surveys of heavily cultivated regions of East Africa has been carried out in Kikuyu Division of Kiambu District, Kenya, by the Nematologist and Mr. L. Kariuki. The object of these surveys is to improve our knowledge of the ecological ranges of *Meloidogyne* spp., and thus enhance the application of control measures under known conditions. In Kikuyu Division *M. javanica* and *M. incognita* var. *acrita* were the dominant species. Sweet potato, maize and banana appeared to possess a measure of resistance to the populations of these species found in the area.

Quarantine Interceptions

During the year several important plant-parasitic nematodes were identified on the roots of imported plants at the East African Plant Quarantine Station. Some of these have not yet been discovered in East African crops and the dangers of importing exotic genera and species which do considerable crop damage is fully realized by the staff of the E.A.P.Q.S.

TABLE 2

NEMATODES INTERCEPTED AT E.A.P.Q.S., 1960

	Pratylenchus sp.	*Pratylenchus brachyurus*	*Pratylenchus goodeyi*	*Meloidogyne* sp.	*Meloidogyne javanica*	*Helicotylenchus erythrinae*	*Aphelenchoides* sp.	*Aphelenchus* sp. ? *avenae*	*Tylenchus* sp.
Liquorice							+	+	
Cocoa		+			+	+	+		
Banana vars... ..			+	+		+			
Fibre pineapple ..	+						+		

+A population of this nematode present in roots.

The steam sterilization technique in use at the E.A.P.Q.S. has been found extremely effective in ridding soil of plant-parasitic nematodes. Tomato and tobacco plants after three or four months' growth in both freshly sterilized and aged sterilized soil showed no trace of attack by either *Pratylenchus* spp. or *Meloidogyne* spp. and no other plant-parasitic nematodes were encountered in root washings.

INTRODUCTION OF PLANTS FROM OVERSEAS

H. H. Storey and F. M. L. Sheffield

Phytosanitary work continues to absorb a considerable amount of time. As Chairman of the Standing Technical Committee, H. H. Storey acts as liaison between the East African territories and the Inter-African Phytosanitary Commission. The Standing Technical Committee and its Subcommittee each held one meeting during the year. P. J. Dickinson, Horticulturist at the East African Plant Quarantine Station continues to act as Secretary of this Committee. Due at least in part to representations from East Africa, certain anomalies in the internationally agreed regulations regarding import control have been corrected. Repeated protests regarding the total prohibition of the importation of scion material of Conifers from Australasia have been successful and such material can now be imported through quarantine. It is expected that East Africa and the Central African Federation will soon co-operate to their mutual benefit in making such importations through the East African Plant Quarantine Station.

A few alterations to the Schedule for Plants entering East African territories have been found necessary. These were mostly of a minor nature and some were due to changes made by the Inter-African Phytosanitary Commission.

F. M. L. Sheffield has continued to serve on the Standing Technical Committee to represent the Quarantine Station, for the scientific supervision of which she continues to accept responsibility.

E.A.A.F.R.O. continues to import all the new sugar cane varieties requested by East African growers and is likely to extend these importations to other species of general interest to the territories.

ANIMAL HUSBANDRY DIVISION

MUGUGA SOUTH FARM

A. F. Dent and Mayda Kapitapa

Buildings. The new building providing accommodation for 52 individually-fed beef animals has been completed and the re-designed cattle yards are almost ready.

The boar paddocks have been reorganized and are being rebuilt to conform with the requirements of the Pig Fencing Ordinance. A further area of land is being planted to Star grass during the short rains and this will be used for another group of sow paddocks.

Individual feeding pens of a new design are being built in the main pig house to replace the existing type These new pens, of which 16 have been completed, are so designed that the amount of spillage will be limited to the absolute minimum.

Pastures. There has been an exceptionally long dry period this year but, despite the long rains being earlier than usual, 32 acres were planted to star grass and oversown with oats and lucerne. Eighteen acres were ploughed up and planted to sweet potatoes. An experimental area of about two acres, which was full of couch grass, was disc harrowed only and star grass runners planted. It is too early, particularly after the long dry period, to give an opinion as to how successful or otherwise these plantings have been.

Forty-two acres of newly replanted star grass pastures were harvested for hay during the year giving a total yield of 85 tons.

Crops

(*a*) *Edible canna*: 6.5 acres were planted this year in two experimental areas and have been used as green food for the pigs.

(*b*) *Oats*: Owing to the abnormal long dry period this year, we have had to depart from our normal practice and have grazed the majority of the oats which have been oversown on the new star grass pastures. Although it is as yet too early to judge, this treatment may have had some adverse effects on the development of the star grass. A small area had the usual treatment and was harvested for oat straw.

(*c*) *Panicum maximum* var. *trichoglume* was planted on nine acres of Soil Physics Division's terrace experiment. The germination of this seed was very disappointing but the "misses" will be planted again during the short rains.

Livestock

Details of the numbers of livestock, with the exception of the twin sets, on Muguga South Farm and Kedong Ranch at 30th September are given in Table I.

Beef Cattle. The following cattle have been purchased during the year:—

(*a*) Boran in-calf heifers from the Northern Province of Kenya.

(*b*) Shorthorn-Zebu in-calf heifers from the Kitui area of Kenya.

(*c*) Shorthorn-Zebu in-calf heifers from the Lake Province of Tanganyika.

(*d*) Boran bulls from E.A.V.R.O.

Identical Twin Herd. Sets of twins have continued to be collected during the year at a very satisfactory rate. Details are given in Table 2. Four experiments have been started using sets of identical twin calves from the uniformity herd.

There has been no serious disease in this herd during the year, although one calf was lost due to "bloat" and another dislocated its hip.

Sheep. A ram and two ewes have been purchased for a foundation herd of Wiltshire Horn sheep.

Pigs. The number of sows and gilts has remained almost stationary during the year. In fact, there has only been an increase of one, and the herd is still well below the target figure of 40 Large White and 10 Landrace breeding females. As stated previously, however, this target will take quite a time to attain owing to the heavy culling programme.

TABLE 1

TOTAL NUMBER OF LIVESTOCK AT MUGUGA SOUTH FARM AND KEDONG RANCH 30-9-60

(excluding twin sets)

Total	CATTLE			
	Cows and Heifers	Calves	Yearlings	Bulls and Steers
	(2 *years and over*)	(*to* 9 *months*)		(2 *years and over*)
168	131	20	2	15

SHEEP	
Ewes	Rams
2	1

Total	PIGS			
	Sow and Gilts	Weaners	Fatteners	Boars
235	35	53	141	6

TABLE 2

TWIN SETS AT MUGUGA SOUTH FARM

Grade Sets		Part Zebu Sets		Zebu*†		
Male	Female	Male	Female	Male	Female	Total
13	7	—	6	9	5	40

* As the breeding history of most sets is unknown. A set is classified as "grade", "part Zebu" or "Zebu" according to type. It is quite probable that some of the sets classified "Zebu" carry fractions of *Bos taurus* blood while those classified grade may have some *Bos indicus* blood.

†Ten of the "Zebu" sets are being used for an experiment in Tanganyika.

The death of two stud boars has reduced the numbers considerably and a new importation of fresh blood will be required in the near future.

General. No major outbreaks of disease have occurred during the year. A new arrangement has been made whereby the Faculty of Veterinary Science at Makerere College, Kabete, are undertaking the Division's veterinary work. The Division would like to express their gratitude to the Director, E.A.V.R.O. for that organization's assistance in this respect in the past.

KEDONG RANCH

A. F. Dent and Jonothan Session

The Division has leased 2,000 acres of typical ranching land in the Kedong Valley for studies using beef cattle and sheep. Water was laid on to a central tank by the lessor, who also built a road and a perimeter fence.

Buildings. A Uniport hut has been erected for a central office and store. A spray race has been erected and four water troughs have been built together with a thorn night *boma* and four African labour houses. In the meantime the cattle have been watered and dipped at the installations of our lessor. The Division would like to record their appreciation for these services.

Pastures. A small area has been cleared of scrub around the buildings to provide space for yards, etc. Temporary thorn scrub fences have been built, dividing the area into four 500 acre paddocks.

Livestock. Two herds of cattle, one Boran and one Shorthorn Zebu, are now running on the ranch. Unfortunately our lessor had an outbreak of foot-and-mouth on his farm at the end of October, and some of our cattle contracted a mild form of the disease.

BEEF CATTLE UNIT

W. J. A. Payne, H. G. Livingston, H. P. Ledger and Nelson Mwangi

A co-operate trial with the Department of Veterinary Services, Tanganyika, on a study of the water requirements and productivity of indigenous cattle when subject to the stress of infrequent watering and long daily treks, has commenced. Ten sets of Zebu-type identical twins collected at Muguga, were transported to the Livestock Research Station, West Kilimanjaro, Tanganyika, early in the year. After a standardization period the experiment commenced on 16th April, 1960. Unfortunately one animal of one set died from snake bite almost immediately after the commencement of the experiment. This set has now been replaced by another set from the Muguga collection.

The twin sets were divided into two groups. The experimental group were managed in exactly the same way as the control group, except that they have been progressively deprived of water for differing periods and have had to walk considerable mileage in addition to the walking done during grazing.

Results from the first 189 days of this trial have been analysed. Rather surprisingly the animals under stress have not lost bodyweight, on the contrary they have gained at an average of 0.28 lb. per day compared with 0.40 lb. for the controls. If it is considered that during the first 189 days, the experimental animals were deprived of water at 48-hour intervals for 63 days and 72 hours for another 63 days; that there were only 16 rainy days with a total rainfall of 2.87 in. during the period; and that at the end of the period the crude protein of the grazings was 4.1 per cent while the crude fibre content was 57.0 per cent, these results are indeed unexpected. The deprived group drank less water than the controls (5.60 compared with 6.51 lb. per 100 lb. bodyweight for the control animals) and individual intake after three days deprivation often approached one-fifth to one-quarter of the animals total bodyweight. There was no significant correlation between intake of water per 100 lb. bodyweight and daily liveweight gain.

In each subperiod of the experiment the blood of both the experimental and the control groups was analysed for packed cell volume, haemoglobin per cent, sodium, chloride and total plasma

protein. During the last period the blood was also analysed for inorganic phosphorus per cent. Deprivation did not appear to be affecting the blood picture in any marked manner. It is tentatively concluded that when the animals are deprived of water, water losses are high, that all or almost all of this water is extra-cellular water, that it is immediately replaced when next the animals drink, and that water intake does not appear to be significantly correlated with liveweight gain under the conditions of this experiment.

The study of the relative efficiency of Boran and Shorthorn Zebu cattle in converting feed into beef has commenced. A random selection of Boran heifers have been purchased from the Northern Frontier District of Kenya and Shorthorn Zebu heifers from the Kitui District of Kenya and the Lake Province of Tanganyika. As calves are born to these heifers they are grouped into fours (no more than 28 days apart in birth date) and one animal of each breed is placed on a high or a low plane of nutrition.

Dr. Livingston has commenced his studies of ruminant nutrition with special reference to the nutrition of cattle in semi-arid areas. His studies are planned to investigate the following facts and hypotheses.

It is becoming evident throughout East Africa that in the semi-arid areas estimates based on the chemical analysis of herbage are a very poor reflection of the nutrient status of cattle, the animals commonly doing much better than expected. It follows that indigenous cattle are either (*a*) much more selective in their feeding habits than has hitherto been thought, or (*b*) they possess physiological mechanisms for extracting more nutrients out of poor herbage than has been attributed to them. Experiments are in progress to study both these possibilities.

Intake Studies on Indigenous Cattle

The first part of this investigation is the establishment of suitable techniques for the study of forage intake in indigenous cattle as many of the methods applicable to temperate stock are unsuitable to local conditions.

Four sets of part-Zebu identical twins are being used and one animal of each set is being fitted with a permanent rumen fistula. (The Division would like to acknowledge the assistance of Messrs. G. D. Phillips and D. Robertshaw of E.A.V.R.O. in carrying out these operations.) After the twins in each set have regained post-operation uniformity, an attempt will be made using individual feeding equipment to measure what these animals are eating in both a quantitative (digestion trials) and a qualitative (rumen fistula

studies) manner. At the same time techniques of collecting ingested material via the oesophageal cardia and rumen fistula will be examined. Oesophageal fistula are considered impractical for the present study hence the desire for intra ruminal collection.

A new type of collection harness has been designed and is in the process of being made as it is intended to continue these studies under semi-arid conditions. Simultaneously the possibility of eliminating the collection harness and bags by the use of the faecal index will be studied.

If the cardial collection techniques work and the faecal index method of studying intake in the field is satisfactory then the experimental animals will move from Muguga to the Kedong Ranch.

When all techniques are satisfactory the first major experiment will be set up. This will have to be carried out initially during the dry season. The following measurements will be made:—

(*a*) Productivity of the four sets of twins in terms of liveweight gain over a defined period (no shorter than three months).

(*b*) Measurement at intervals of—

(1) quality of feed as measured at the cardia in the fistulated twins;

(2) quality of feed as measured by faecal index techniques.

(*c*) Assessment of quality of feed by a forage sampling technique based on a behaviour study and availability of different species in the area grazed.

This experiment should determine—

(*a*) what species the cattle actually eat when allowed to exercise selection during grazing;

(*b*) the nutrient value of what the animal actually eats;

(*c*) whether the chemical analysis of actual intake correlates with the animal's level of productivity;

(*d*) whether the nutrient value of what the animals actually eat is compatible with the nutrient value of the available pasture and browse in the experimental area as determined by conventional sampling methods.

Metabolic Stress and Nitrogen Excretion in Bos taurus *and* Bos indicus

Under alternative (*d*) above it is possible that indigenous cattle possess a nitrogen sparing mechanism, as has been reported for the camel, and practical observation would support this assertion. An

experiment has commenced utilizing one set of Zebu and one set of Ayrshire identical twins. Nitrogen pathways will be studied to determine if, under conditions of protein stress, indigenous cattle block normal urea excretion, thus allowing non-protein nitrogen to continuously recycle as a possible food source for rumen micro-organisms. If this line of investigation shows promise then future studies will include wild game ruminants so that the comparison exotic, indigenous and wild ruminants can be made.

A draft memorandum on the planning and operation of live-weight gain trials has been circulated to all the territories. The original request for this was made by Uganda and it is hoped to present a revised memorandum to a conference to be held in Uganda late in 1961.

PIG UNIT

W. J. A. Payne, H. G. Livingston and J. G. Rimono

The co-ordinated pig research programme being conducted by the Kitale, Eldoret and Ol Joro Orok stations of the Kenya Agricultural Department and the Naivasha station of the Kenya Veterinary Department on evaluation of the Pig Industry Board's protein and mineral supplement has continued. Results are published by the individual stations, the most important results to date showing that maize is not a suitable cereal to use as the sole component of the cereal part of a bacon pig's ration (Kitale) and that there is a definite relationship between the price of skim milk and its utility in replacing the P.I.B. supplement in the bacon pig's ration (Eldoret).

At Muguga the experiment conducted on the effect of farrowing equipment and the microclimate on the incidence of piglet mortality has been completed. Some of the results are shown in Table 3 and this experiment is now being written up for publication. A new management experiment has been commenced comparing the productivity of both Large White and Landrace pigs on deep litter and in conventional housing.

Other investigations at Muguga that are continuing are, (*a*) the effect of environmental temperature on the nutritional demand for iron and the incidence and severity of anaemia in piglets, (*b*) the use of synthetic oestrogens with *ad lib* rations and their effect on carcass composition, and (*c*) the effect of varying the percentage of individual amino-acids in a protein supplement. The first results from the latter trial suggest that methionine may be a limiting factor in local protein supplements.

A survey of the cause of "soft setting" fats in pigs has been conducted for the Pig Industry Board. The returns have been analysed and interpreted using a punched card technique. It is now believed that many of the reasons for pig producing "soft setting" fat have been elucidated as the result of this survey. The results are being assembled for publication.

TABLE 3

THE EFFECT OF FARROWING TREATMENT ON THE INCIDENCE OF PIGLET MORTALITY DURING THE PERIOD 1ST JUNE, 1958-1ST JUNE, 1960

	Round House		Conventional House	
	Heat	No heat	Heat	No heat
No. pigs on experiment	162	101	242	98
Per cent stillbirths	3·09	7·92	4·54	5·10
Per cent laid on	2·47	5·94	9·50	11·22
Per cent died other causes up to 56 days	12·34	11·88	4·96	7·14
Per cent total mortality to 56 days ..	17·90	25·74	19·00	23·46
Per cent post-natal to 56 days (all causes)	14·81	17·82	14·46	18·36

MEAT UNIT

H. P. Ledger and W. N. O. Gichuru

Routine carcass analyses continued throughout the year and a start was made on chemical analyses of meat samples which had accumulated in deep freeze storage. This section of the work continues to be a bottleneck in the organization of the unit and it was unfortunately necessary to discontinue taking samples from all carcasses owing to lack of storage space. Deep freeze storage seems to be eminently satisfactory for meat samples and it was found that wide-necked, screw-topped glass jars were better containers than polythene bottles or bags as they facilitated drying and handling in the laboratory at a later date.

Analysis of muscular tissue confirms that the water content for *Bos indicus* lean on a fat free basis is close to the 77 per cent quoted in the U.K. for *Bos taurus* cattle.

The widely differing fat content of specific muscles from the same carcass underlines the danger of predicting the intramuscular fat content of a carcass from samples taken from a single site. Although it is usual for there to be more "marbling" fat in the "eye"

muscles of the fatter animals this was not invariably so. A few fat carcasses were noted to have very little marbling and conversely the occasional lean carcass was quite well marbled.

Results of the statistical analysis of the tenth rib sample joints referred to in last year's Annual Report indicate that the following formulae can be used for predicting the composition of the whole carcass from that of the tenth rib joint of *Bos indicus* cattle of the Boran type. Full details are given in a paper that is being prepared for publication.

For the prediction of lean

(i) *In carcasses of either sex*

(*a*) Percentage of lean in carcass = $0.431\ X_1 + 0.475\ X_3 + 33.58$ (subject to a standard deviation of 1.53 per cent).

For the prediction of total fat

(i) *In steer carcasses*

(*b*) Percentage total fat in carcass = $0.664\ X_2 - 0.78$ (subject to a standard deviation of 1.34 per cent).

(ii) *In cow carcasses*

(*c*) Percentage of total fat in carcass = $0.641\ X_2 + 0.23$ (subject to a standard deviation of 1.13 per cent).

For the prediction of bone

(i) 100 - (Equation (*a*) + Equation (*b*) or (*c*)).

(*f*) Percentage of Lean in carcass = 100 − (d + e).

For all equations X_1 = % lean in sample rib joint.
X_2 = % total fat in sample rib joint.
X_3 = % butchers bone in sample rib joint.

A preliminary analysis of the composition of the three Kenya grades of beef, described in detail in the current grading regulations of the Kenya Meat Commission as "1st", "A" and "Local", shows a progressive increase in the amount of fat present as the grading falls from "1st" to "local" grade. Tables 4 and 5 show the differences in composition of the carcasses of the three grades and from these it can be seen that the barrel (i.e. loin, neck and thorax) of the animal becomes an increasingly higher proportion of the carcass as the grading deteriorates. This underlines the fact that the market demand is for immature beef. The high proportion of hind quarter to forequarter of these Boran steers is worthy of note as is the low percentage of bone and the high killing-out percentage. All of these steers were reared on grass without supplementary feeding, and the overall daily liveweight gain from birth to

slaughter was in the region of 0.60 to 0.75 lb. per day. It is of interest to note that the percentage of fat, viz. 28.4 per cent for "1st" grade carcasses agrees very closely with that of 28 per cent quoted as being the optimum fat content for a good commercial carcass in the United Kingdom.

An additional check on the standing of the local cattle and their grading in relation to world markets was carried out by using the system of scoring, based mainly on carcass measurements used successfully by McMeekan and Hammond in selecting carcasses for the Smithfield show. By testing the same steers in order of points gained of linear measurements under this system and dividing them into similar groupings to the K.M.C., grading tables of composition (Tables 6 and 7) were obtained.

From figures kindly supplied by Dr. McMeekan of the Ruakura Animal Research Station, New Zealand, it is possible to make a comparison of the points scored on measurement for the Boran steer carcasses with those of good commercial New Zealand carcasses and with Smithfield show carcasses. Such a comparison is shown in Table 8.

Dr. McMeekan commented that "the first five steers were typical of what we call G.A.Q. (Good Average Quality) which is a special New Zealand export grade. The remaining five would definitely be second grade".

An interesting development during the year has been the initiation of co-operative work with the game authorities in order to compare the carcasses of game animals with those of cattle, as meat producers.

TABLE 4

COMPONENTS EXPRESSED AS PERCENTAGE COLD DRESSED WEIGHT ON K.M.C. GRADING

Grade	No. steers	H.Q. 10/11 rib	Hind leg	Loin	Fore-leg	Neck-thorax	Cold carcass wt. (lb.)	K.O.* %
"1st" ..	18	53·1	31·2	21·9	12·6	34·3	649	59·7
"A" ..	17	52·6	30·1	22·5	12·2	35·2	641	60·1
"Local"	6	52·2	28·9	23·3	11·6	36·2	676	61·5

*The K.O. per cent is the cold dressed carcass weight expressed as a percentage of the starved slaughter weight of the steer.

TABLE 5

COMPONENTS EXPRESSED AS PERCENTAGE COLD DRESSED WEIGHT ON K.M.C. GRADING

Grade	No. steers	Total fat	Total lean	Total kidney hump	Total true bone	Total in-edible products *	Total edible products
"1st" ..	18	28·4	55·1	2·4	9·9	4·2	85·9
"A" ..	17	30·0	53·8	3·1	9·4	3·7	86·9
"Local" ..	6	34·9	48·5	4·0	8·6	4·0	87·4

* Total inedible products excludes true bone but includes bone scrapings (periosteum), coarse connective tissue, cartalidge tendon ends and dissection bases. "Butchers bone" can be considered to be the sum of true bone and inedible products.

TABLE 6

COMPONENTS EXPRESSED AS PERCENTAGE COLD DRESSED WEIGHT ON MCMEEKAN'S GRADING SYSTEM

Grade	No. steers	H.Q. 10/11th	Hind leg	Loin	Fore-leg	Neck thorax	K.O. %
"1st" ..	18	52·8	30·7	22·1	12·5	34·7	59·5
"A" ..	17	52·8	30·1	22·7	12·2	35·0	60·8
"Local" ..	6	52·7	30·4	22·3	12·3	35·0	60·2

TABLE 7

COMPONENTS EXPRESSED AS PERCENTAGE COLD DRESSED WEIGHT ON MCMEEKAN'S GRADING SYSTEM

Grade	No. steers	Total fat	Total lean	Total kidney and hump	Total true bone	Total inedible products *	Total edible products
"1st" ..	18	28·6	55·0	2·6	9·6	4·2	86·2
"A" ..	17	30·8	52·7	3·2	9·3	4·0	86·7
"Local" ..	6	32·0	51·6	2·9	9·6	3·9	86·5

*Excludes true bone.

TABLE 8

COMPARISON OF POINTS SCORED ON LINEAR CARCASS MEASUREMENTS

Points for	40 good commercial N.Z. carcasses	Smithfield Show: 10 best carcasses in each group				10 best Boran steers
		Class I		Class II		
		1956	1957	1956	1957	
Carcass wt.	610	575	579	644	644	
Fatness of meat ..	11	13	15	14	12	13
Fat cover	11	13	13	12	12	12
Blockiness	12	13	13	14	13	7
Balance	7	9	9	9	7	10
Wt. suitability	4	4	4	4	4	4
Score	45	52	54	53	48	46

BIOCHEMICAL UNIT

Mrs. A. E. Bazin

In the routine biochemical laboratory, chemical estimation of the hardness of fat samples from all experimental pigs has continued. 400 samples have been analysed this year, 250 from Muguga and the remainder from Kitale, Eldoret, Ol Joro Orok and Naivasha experimental stations.

Work has also continued for the Beef cattle and Meat Units. A large number of pocked cell volume determinations on blood samples and crude protein analyses of pasture grasses and legumes have also been made.

The assistance of M. T. Friend of this organization and D. Horrocks of E.A.V.R.O. in carrying out a large number of routine biochemical determinations for this Unit is acknowledged.

FORESTRY

SILVICULTURE RESEARCH

A. L. Griffith and P. Howland

Work during the year has in general continued on the long-term lines laid down for us in 1952. This programme was intended to last for at least ten years and will be reconsidered and revised in late 1962, after the meeting of the Eighth British Commonwealth Forestry Conference which will be held here in East Africa. The Committee of this Conference, which appraises the forestry of the host countries, will no doubt give us a frank criticism of the work of E.A.A.F.R.O. since its inauguration.

The Silviculturist was awarded a F.A.O. Fellowship, and in the latter part of the year attended a Seminar and Study Tour on the conifers of Latin America in Mexico, British Honduras and Cuba. This party consisted of 30 delegates from 25 countries.

The Specialist Committee of Forest Research held its sixth meeting at Muguga in July. Particular attention was paid to seed orchard work, with its difficulties and dangers of the importation of green material, and Yield Tables.

In August we held the eighth Forestry Course at Muguga. This is an annual event and it was attended by 16 delegates from the East African territories, including four African Assistant Foresters from Uganda. We have now had 131 Assistant Conservators and Foresters on the courses. In June, the Forest Ranger Class of the Tengeru Natural Resources School (Tanganyika) camped with us in Muguga for a week of intensive forestry instruction. In May, a party of local Boy Scouts camped at E.A.A.F.R.O. for a weekend and were given training in tree pruning, as the planting season was over. Their normal training is in tree planting.

The year 1960 has been the second consecutive year of low rainfall. The "long" rains of March, April and May produced only some 70 per cent of their normal amount. We were, however, able to plant successfully at the end of March which was some five weeks earlier than in 1959. The climatic conditions this year although not as difficult as 1959 have nevertheless again completely proved the validity of our theories, and experimental evidence from short-term experiments on soil moisture at planting time, the date and conditions for "safe" planting, plant exposure and storage, and depth of planting. The total rainfall of the year was 67 per cent of the normal.

When reading this report it must be realized that our "long" rains occur in March, April and May, and hence our nursery experiments, our short-term experiments and all our routine planting is done in this period. These experiments are measured and assessed in the following March and hence most of the results in this report are at least nine months out of date. The experiments of 1960 will not be measured until March, 1961, and hence results will appear in next year's report. In this report we can only give what we consider their indications after six months.

An interesting new approach this year in the short-term experimental work is an investigation into the root development and mycorrhizal production during the period immediately following planting in the field. This work is described under short-term planting out problems. This first year's work has disabused us of the idea (so often held) that because little or no growth activity above ground can be seen and measured in the first few days or weeks after planting, great activity in root growth and new mycorrhizal establishment was not taking place underground.

We have this year completed the first rotation (five years) of an investigation of the relative fuel yields of three eucalypts. In this large-scale replicated experiment we have now measured the calorific value yields as well as the usual variables such as solid and stacked volume, height, diameter, basal area, etc., per acre. (*See* later in section on "Short-term Tree Cropping".)

The headings of the report that follows are those of the long-range programme.

I. INFORMATION SERVICES

The Forest Bureau was maintained and expanded and now contains 2,003 Specific Ledger Files and 908 General Ledger Files. The issue of further lists of highlights of information ledgered has continued and is much in request.

Many inquiries were received and answered and it has been our pleasure to welcome many visitors and show them something of our work.

II. STANDARDIZATION OF RESEARCH PROCEDURE

This has been kept under revision and some minor modifications have been adopted.

III. RESEARCH ON SOFTWOODS

In the following report on seed, nursery problems and seed orchards, Mr. W. B. May (Horticulturist) has collaborated. The general procedure has been that the experiments are designed by the Silviculturist, the actual work in the nursery is carried out by the Horticulturist, and the measurements and the assessment of results done by the Silviculturist.

A. Seed Problems

Cotyledon Numbers

The long-term experiments planted out in 1954 (E.P.4a) and 1955 (E.P.4b) with *C. lusitanica* of two, three and four cotyledons, and in 1954 (E.P.7) with *P. patula* of four to nine cotyledons, *P. caribaea* (now *P. elliottii*) of four to nine cotyledons, *P. radiata* of seven to nine cotyledons and *C. lusitanica* of two to four cotyledons were continued. In 1960, after six and five years respectively, no significant differences in height, breast height diameter or survival percentage have yet resulted.

Size of Seed

The long-term experiments planted out in 1954 (E.P.3a) and 1955 (E.P.3b) with *C. lusitanica* of five different sizes of seed were continued. In 1960, after six and five years respectively, no significant differences in height, breast height diameter or survival percentage have yet resulted.

Canker Incidence

In all the above cypress experiments counts of canker (*Monochaetia unicornis*) attack were made. The incidence varies greatly from tree origin to tree origin and also with the number of cotyledons of the seedling and the size of the seed. No definite pattern has yet shown itself but it appears possible that this will emerge in the next few years, and may give us further insight into cypress hybridization. This again demonstrates the importance of long-term research into such apparently short-term problems.

Seed Orchards

The progress of this work was discussed by the Specialist Committee on Forest Research and by the Forest Research Coordinating Committee. Future plans will be clarified after the F.A.O. Study Tour of Latin America and the visit of the Silviculturist, Northern Rhodesia, to the Philippines and the Far East. The bottleneck is likely to be the time necessary for green material to be in quarantine and the limitations of space in the Muguga Quarantine Station. The dangers of the importation of green

material from certain parts of the world have been discussed at length during the year. The foreign visits of a number of East and Central African foresters have been of the greatest help in clarifying the situation.

B. Nursery Problems

(Experiments started in April, 1959, and concluded in March, 1960)

Experimental work in the nursery at Muguga continued. This is long-term work for in our very variable climate many years of repetition are required to cover the climatic range. Weather variations have been great and in the past eight years since we started this work we have had one nearly normal year, two years above normal and five years below normal for rainfall. This present year (1960) is again a year of deficient rainfall as the "long rains" were 30 per cent below normal and the total rainfall of the year was 67 per cent of the normal.

Fertilizers

The experiments described in previous years' reports were repeated in 1959 (measured in 1960). They were with *P. patula* seedlings and serve as a general control of our minimum fertilizer experiments. We now have eight years' repetitions. N.P.K. were applied in all combinations and at three rates which were:—

Fertilizer rate 0.		No fertilizer.
Fertilizer rate 5.	N.	Sulphate of ammonia (20 per cent N.) 540 lb. per acre or 8 gm. per box.
	P.	Double superphosphate of lime (39 per cent soluble P_2O_5) 540 lb. per acre or 8 gm. per box.
	K.	Sulphate of potash (52 per cent K_2O) 270 lb. per acre or 4 gm. per box.
Fertilizer rate 10.		Twice the above quantities.

These rates are called "5" and "10" as they are 5 and 10 times the rates which are normally used in agriculture in the United Kingdom. These experiments confirmed previous years' indications and so far in eight years' work we have had no contradictory results. The general indication is that there is little or no difference in response between the "5" and "10" rates of application and hence the latter rate is unnecessarily high. In consequence, in 1955 experiments were started to try and find out the *minimum* fertilizer requirements.

Minimum Fertilizer Requirements

In view of the above, experiments were started in 1955 to measure the response of seedlings to lower fertilizer rates. Three years' experiments with two pine species failed to show any appreciable response to fertilizer applications of less than rate "5" described above.

The experiments were continued in 1958 and repeated in 1959 but the soil mixtures used were (*a*) Muguga Standard Mixture (without basic N.P.K.) and (*b*) Muguga Standard Mixture (without basic N.P.K. and without horse manure). Two species were used (*P. radiata* and *P. patula*), but results have been inconclusive and we are still without any indication of what the minimum fertilizer requirements are at Muguga.

Effect of Restricting Evaporation in Transplant Boxes

This subject was repeated for the fifth (and last) year. Treatments were (*a*) boxes sunk to ground level, (*b*) boxes placed normally on a gravel base and (*c*) boxes placed normally on a gravel base but mulched with chopped straw after the short rains, i.e. for the dry season of January, February and March. The species used were *P. patula* and *P. radiata.*

The results confirmed those of previous years that the sunk boxes and the mulch definitely increase the height growth of both species and that *P. patula* is far the more sensitive species. It appears unnecessary to sink boxes (with its considerable extra expense) if one is prepared to water adequately. If one is not prepared to water adequately, or if one is unable to water adequately, there is no justification for establishing a nursery. Both sinking the boxes and putting on a mulch aggravated termite troubles.

Transplant Spacing in Beds.

This experiment had to be abandoned owing to severe casualties.

C. Short-term Planting-out Problems

These short-term experiments were started in 1952 to compare different establishment techniques. So far 120 experiments have been completed and 15 were started in the long rains of 1960. The results as summarized are often only tentative and the experiments must be repeated over a number of years in order to cover the climatic range.

A summary of the first five years' results was given to the Seventh British Commonwealth Forestry Conference in Australia in 1957 and a summary of the first ten years' results will be presented to the Eighth Conference which is to be held in East Africa in 1962.

Different Dates of Planting

We have now seven years' experimental evidence of weekly planting from the middle of March to the end of May each year for *P. patula, P. radiata* and *C. lusitanica.* With all three species height growth and survival percentage drop markedly with late planting. In these experiments at each date of planting an estimate of the depth of soil wetting is made and from the rainfall records the rainfall "build up" is calculated daily allowing for the daily evaporation.

We have now had two years which have been very difficult climatically owing to the shortage of rainfall, but following the criteria shown by our short-term experiments routine planting has been completely successful. It is of interest that in the last two years the best date of planting as shown by the experiments differed by about five weeks in time.

Our short-term experiments and the conclusions drawn from them have thus been completely justified in two consecutive poor climatic years.

This once again shows the value of these short-term experiments. They are cheap and easy to do, and only occupy a very small area. They can and should be done at any Forest Station anywhere in the Commonwealth to study local establishment problems.

The difference in mean height growth between early and late planting was approximately 40 per cent and in the percentage of survivals about 24 per cent. This in a very poor climatic year.

Comparison of Different Depths of Planting

We have now done 12 experiments on the subject over six years with *P. patula, P. radiata* and *P. leiophylla.* In this work plants have been planted (*a*) at the collar, (*b*) 2 in. above the collar and (*c*) 4 in. above the collar. The general result is that deep planting does not result in any deleterious effect but causes a stimulation of height growth up to some 30 per cent. This extent of the stimulation of course depends on the climate of the year. This confirms work in the U.S.A. on deep planting the Southern Pines.

Comparison of Bare-rooted and Ball-planted Transplants

A number of experiments have been done over the last six years with *P. patula, P. radiata* and *C. lusitanica.* Indications are that in the climatic conditions of Muguga it is well worth while to take the extra trouble and small extra expense and use ball-planted plants. This has been completely demonstrated by the experiments of the last two years of difficult climatic conditions.

In the last year results were:—

Species	Survival percentage	
	Ball planted	Naked rooted
P. patula	85	23
C. lusitanica	98	19

In a really good year naked rooted stock does as well as ball-planted stock. It must however be realized that at the time of starting the nursery stock it is not possible to estimate whether the following long rains will be good, normal or poor.

Effect of Storage of Naked Rooted Stock

A further experiment was done with *P. patula* as it is one of our more sensitive species. The stock was lifted and all soil shaken off the roots. It was then bundled in wet gunny, taken to the planting site and one set planted immediately. The second and third sets were thoroughly wetted and left for 24 hours and 48 hours respectively before planting. The indications of six years' work are that *P. patula* is more sensitive than *P. radiata* but both species can be stored thus for 48 hours if necessary. *The practice is, however, to be deprecated and planting should be done as soon after lifting as possible.* These indications have been completely vindicated under the hard climatic conditions of 1959 and 1960.

Effect of Exposure of Naked Rooted Stock

Parallel to the above experiment naked rooted stock of *P. patula* was (*a*) planted at once, (*b*) exposed for 15 minutes, (*c*) exposed for 30 minutes, (*d*) exposed for three hours and (*e*) exposed for six hours. This year's experiments have shown that exposure for 30 minutes is fatal and thus confirms five years' experiments that it is dangerous to expose plants for more than about 15 minutes. This explains many plantation failures where the plants were probably dead before they were planted.

Comparison of the Best Plants with the "Runts" from a Nursery Bed

Two further experiments were done with *P. patula* and *P. radiata* in this subject. This completes six years' work. These experiments confirmed that there is little difference in survival percentage and actual height increment between the two classes in the first year. The difference in the sturdiness of the best plants and their success in the race against the weeds is very marked. The general increment in the first year is about 20 in., and this put on to a 2-ft. plant is very different in effect from the same increment put on to a 1-ft. plant.

Planting Stock Raised by Different Box and Bed Techniques

Two further experiments were done in which the best bed plants were compared with the best box plants. The species used were *P. patula* and *P. radiata*. These experiments over six years have shown that under Muguga conditions it is not worth while to use the cheaper bed method. The use of boxes is more expensive but it is a worth while insurance against failure in adverse climatic conditions. This has been conclusively demonstrated in the two poor climatic years of 1959 and 1960.

Rate of Growth of New Roots and New Mycorrhiza Immediately after Planting

We have always assumed that because very little height growth occurred in the first three or four weeks after planting that little development took place underground in this period. An investigation was started this year (1960) to find out what really happens underground immediately after transplanting. In a short-term experiment, plants of *P. patula, C. lusitanica* and *Euc. saligna* were planted (*a*) normally in the ground, (*b*) normally in the ground but up against a piece of plate glass sunk in the ground and (*c*) in a box with a plate glass front. We were thus able to see what was happening underground in (*a*) by digging up sets of plants at intervals (we, of course, could not replant them), in (*b*) by scouring out the litter and debris which had been put in the pit in front of the plate glass and in (*c*) by opening the wooden shutters over the plate glass in the front side of the box. The reason for the treatments is that in (*a*) once a plant is dug up for observation it cannot be replanted and in (*b*) the daily observation is a dirty and rather acrobatic feat. If the boxes in treatment (*c*) are comparable with (*a*) and (*b*) it makes the investigation simpler, more accurate and more congenial. In all treatments and in all species both ball-planted and naked rooted transplants were used.

General results of this first year's exploratory experiment are that new roots are produced as early as the first week after planting. The first new mycorrhizal development also occurred on pine seedlings as early as the first week after planting. The interesting observation was that the roots of the newly planted transplants grew out of the 1-ft. cube planting hole in from 12 to 70 days, i.e. in one and a half weeks to six weeks. This fact is of the greatest importance in termite areas where it is only possible to treat the soil in the planting pit with anti-termite insecticides.

Two other new short-term investigations were started in 1960, but results will no be available until March, 1961. The first is the effect of planting stock (of the same origin, age, etc.) into pits prepared during the dry weather, i.e. some six weeks before planting, and into pits prepared on the day of planting.

Another new short-term investigation started in 1960 is the effect of badly planted stock as compared with well-planted stock. We have had a lot of trouble with, for example, *P. radiata,* of alleged wind throw at about two years old. The wind throw is not however always in the direction of the wind and appears often to be due to careless planting. This new investigation includes treatments of deliberate malformation of the root systems into L and J shapes at planting.

Cover Crops in Young Cypress Plantations

Observation of the experiments started in 1954 (E.P.5) was continued. *Prunus salasii* continued to be the most successful cover crop. It is of interest that the cover crops have had little or no effect on height or diameter growth.

Effect of Shamba Crop and Cultivation

Observation was continued on the experiment which was started in 1955 (E.P.11) in conjunction with the soil physics division to study the effects of *shamba* crops on the height growth and survival percentage of the forest crop of pine. The *shamba* crops were (*a*) maize, (*b*) beans and (*c*) maize and beans. The *shamba* crops had little or no effect on survival percentage. In the first year the crops reduced the pine height growth by some 10 to 15 per cent. No *shamba* crops were possible after the second year, but even after five years their retarding effect was still present to the extent of maize and beans 6 per cent, maize 5 per cent and beans alone 2 per cent.

D. Long-term Problems

We now have 13 sample plots covering nine species and plan to lay out another four plots in 1961.

The two experiments started in 1958 to test the effect on the height and diameter growth of *Pinus radiata* (E.P.17) and *Cupressus benthamii* (E.P.20) of annual pruning to one-half tree height, two-thirds tree height and threequarters tree height up to 30 ft. were continued. At the end of the second year of treatment the increment in height growth has been retarded by some 14 to 28 per cent and the diameter growth by some 40 to 60 per cent depending on the intensity of the pruning.

E. Species Trials (Mainly Exotics)

Arboretum

Six new plots were planted during the year. Three are new species (two *Agathis* spp. and *Vitex keniensis*); the other three are different seed origins of existing introductions. We now have 220 plots of 165 species of which 51 are eucalypts (76 plots), 24 pines (38 plots), 15 cypresses (18 plots), 10 acacias (14 plots), 5 *Callitris* (10 plots) and 60 other species (64 plots).

As reported last year some species have shown remarkable growth. The height given is the "top height", i.e. the mean height of the best 100 trees per acre. The plots are approximately one-tenth of an acre in area and the top height measured in each plot is thus the mean height of the ten tallest trees. The diameter given is the mean d.b.h. of all the trees in the plot.

To the 16 species listed in last year's report (all of which have continued to grow well) should be added the following:—

Eucalyptus pilularis
48 ft. and 6.2 in. diameter in six years.

Euc. crebra
30 ft. and 4.6 in. diameter in six years.

Tristania conferta
40 ft. and 4.4 in. diameter in six years.

Euc. scabra
38 ft. and 4.7 in. diameter in four years.

Euc. obliqua
45 ft. and 4.7 in. diameter in three years.

Euc. bicostata
42 ft. and 4.8 in. diameter in three years.

Cupressus lusitanica (Kenya selected seed)
18 ft. in three years.

Pinus patula (Kenya selected seed)
14 ft. in two years.

Live Hedges

All the existing hedges (except *Hakea saligna* for which seed was not available) were replicated in an adjacent plot in late March, 1960. The object is to find out the most suitable and cheapest management technique to achieve an efficient hedge for each species. We are trying to find methods which are economically applicable in large-scale farming. At a later stage each species will be tested for its fire resistance.

International Eucalypt Trial (I.U.F.R.O.)

This consists of five replications of 12 species or strains of eucalypts and has been repeated in 18 countries. It is now three years old and continues to grow well.

IV. ENUMERATIONS AND V. REGENERATION OF HARDWOODS

Work continues in these subjects. E.A.A.F.R.O.'s contributions were purely advisory.

VI. SHORT-TERM TREE CROPPING

The replicated ten-acre experiment to test the relative fuel yields of three eucalypts reached the end of its first rotation at five years old and was felled and measured in March/April, 1960. The species are *E. grandis* of Australian origin, *E. saligna* of Australian origin and *E. saligna* of local origin (known to be a hybrid of *E. saligna* and *E. grandis*).

In this experiment we measured the calorific value yields per acre as well as the usual variables such as solid and stacked volume, height, diameter, basal area, etc.

It is of particular interest that although the three crops looked entirely different (particularly with regard to their effect on the ground flora) and varied in height, diameter, volume, etc., yet their caloric yields per acre were very similar.

An experiment (E.P.18) to test the effect on stool mortality of felling at ground level by axe and saw in a six-year-old crop of *E. saligna* showed that 15 months after felling the axe felling had regenerated by 96 per cent and the saw felling by 100 per cent.

A new experiment (E.P.25) to test the effect of the fuel and pole yield of reducing two-year-old *E. saligna* coppice regeneration to varying numbers of stems per stool was started during the year. The coppice was reduced to the three, two or one best stems per stool.

During the year three new experiments were started in the Arboretum plot of the six-year-old bamboo *Oxytenanthera abyssinica*. They are designed to find out (*a*) the length of life of an individual culm (E.P.23), (*b*) the rate of growth of new culms (E.P.24) and (*c*) the yield of culms by weight (i.e. in tons per acre) when the clumps are thinned annually (E.P.22). This information is of vital importance to a paper industry. It is far too early to be definite, but the results of the past few years appear to show that about 50 per cent of the culms can be cut each year and will yield about seven to ten tons of green material or about three to five tons of dry material per acre.

VII. YIELD TABLES FOR IMPORTANT SPECIES

As a result of the Forest Specialist Committee meeting it is hoped that the Yield Tables for the cypresses of the *C. lusitanica* group will be completed in 1961.

VIII. MUGUGA (E.A.A.F.R.O.) ESTATE

The conversion of the estate from wattle to softwoods for experimental purposes, species trials, and to eucalypts to provide fuel and poles for the station is now complete.

A Working Plan for the forest areas of the estate is under preparation.

FOREST ENTOMOLOGY

Tecwyn Jones and W. Wilkinson

The work of this Division has continued along the lines indicated in the previous report, but although the junior staff position has improved, the lack of essential equipment has severely limited progress on basic biological problems.

Present studies, and problems pertaining to East African forest entomology in general, were brought to the attention of the Commonwealth Conference and the International Congress of Entomology in London and Vienna by Tecwyn Jones who visited Europe in July as official High Commission delegate. It was evident from discussions at these Conferences that the problems of borers in living trees and termites in relation to afforestation are widespread not only in Africa but throughout tropical and subtropical forest areas. Co-operative research by entomologists in these areas is highly desirable, particularly for the development of rapid and reliable methods of diagnosis and assessment of infestations. The Commonwealth and International Congresses successfully provided opportunities for initiating such co-operation.

The work of the Division was also brought to the attention of the East African public, by an exhibit at the Royal Agricultural Show held at Nairobi in September. The display, which depicted the three major aspects of interterritorial studies, namely the forest insect survey, tree-borers and termite investigations, was well attended and aroused considerable interest. The high standard of the three enormously enlarged photographs of insect life by C. A. Spinage of this Organization, and a working model of a Saturniid moth were highly commended.

The East African Timber Advisory Board has requested advice and guidance on the compilation of importation regulations for preventing the introduction of new pests into the territories via timber imports, packing cases and dunnage. Mr. Jones who attended the Board meeting at Moshi, has been responsible for reviewing legislation in force in other countries and for drafting proposals for similar quarantine regulations suitable for East African conditions.

Visitors

There was an increase in the number of visitors and inquiries. Working facilities and assistance were given to Dr. David H. Kistner and party, of Chicago State College. Dr. Kistner was making a collecting survey of myrmecophiles associated with Doryline ants in connexion with his revision of the Pygostenini.

In co-operation with territorial specialists, a periodical entitled *Pest Digest* has been issued quarterly, for distribution within the forest departments. It is aimed at keeping forestry workers informed of current research, and stimulating their interest in pests and diseases. Its editor, Dr. I. A. S. Gibson, Pathologist of the Kenya Forest Department is accommodated in the E.A.A.F.R.O. laboratories.

East African Forest Insect Survey

The survey, despite its importance, has continued to function at a reduced level due to a shortage of trained staff. The identification service continues, and there has been a marked increase in the volume of termites submitted for naming, chiefly by the territorial forest departments.

ESTABLISHED FORESTS AND PLANTATIONS

Tecwyn Jones

Visits to borer-infested forests have included local areas, the Aberdares and Mount Kenya plantations in Kenya, and the Meru, Kilimanjaro, West Usumbara Mountains and the Eastern Province in Tanganyika.

Field investigations in Kenya have been largely confined to *Oemida*. The possibility of detecting the borer by non-destructive techniques and observations on infestations in game-damaged areas have formed the major aspects of this work.

In Tanganyika the field of study was extended to include *Androeme*, a few defoliators, the Mvule gall, the shoot borers *Hipsipyla* and *Tragocephala* on *Khaya nyasica* and *Cedrela mexicana*, and pinhole borer and weevil attack on girdled and poisoned trees. The most important single contribution, however, was the discovery and investigation of the *Isoberlinia* borer in the Kwamkoro area. This insect bores holes of several inches diameter throughout the length and breadth of the heartwood of *Isoberlinia scheffleri*. Its depredations are spectacular and can be so extensive as to render mature and large sized trees completely valueless as timber. The borer has been identified, from larval skins and one badly damaged and incomplete adult, as being a longhorn beetle of the family Lamiidae, but its exact identification is still awaited from specialists in Europe. Laboratory investigations of infested timber have shown that the larva bores through to the heartwood core of the tree via the dead tissues in the stub ends of broken, or self-pruned branches. In this respect it resembles *Oemida* and furthermore, like *Oemiida*, it leaves no external evidence of its presence within the tree. Oviposition, however, if typically Lamiid, is confined to niches or underbark cavities and eggs are not laid on tissues devoid of bark. This factor alone could prevent the insect from infesting converted timber.

Investigations on basic biology of *Oemida* have made little progress, though the use of the respirometer method of assessing activity has continued without any experimental difficulties. No satisfactory method has yet been devised whereby activity can be recorded graphically from the sounds produced by the boring larvae, but recent ideas seem more promising.

The problem of non-destructive tree inspection has been pursued at some length in the past year. During a visit to Europe discussions were held with various experts and at certain institutes in Britain and France, in the hope that some reliable technique could be found. Prior to this a few small trials were conducted in Nairobi. The outcome of these investigations and discussions was, however, disappointing. Sonic methods are unreliable. Ultrasonic techniques are beset with technical difficulties and like X-ray methods are much more suitable for laboratory investigations than for field work. Gamma-radiography and the use of isotope sources and scintillation counters are too hazardous and too unreliable,

respectively. The only solution now rests with the modification of the first approach to the problem, i.e. the increment borer method. This in itself is too slow but a more rapid drilling device is now under consideration, which has been used with success for a different purpose in the U.S.A. A statistical sampling programme has been devised, especially for this mechanical borer, in conjunction with the statistical unit at Rothamsted.

Studies on the nutritional habits of wood boring larvae and the assessment of minimum food requirements, were interrupted by the departure of the analyst on long leave. It is hoped that this specialized subject of wood analysis will be recommenced with the help of British and French specialists.

TERMITES AND AFFORESTATION

W. Wilkinson

The problem of insect attack on young trees, and the initial steps taken to assess it, was stated in the 1959 Report,

Work has progressed on the lines initiated, but has been directed mainly towards closely observed field experiments, using facilities largely supplied by the Kenya Forest Department.

In the initial experiment at Uuni Hill, Machakos, various formulations of Aldrin and Dieldrin were applied in the planting holes of *Eucalyptus paniculata,* at a strength of 0.025 oz. of active ingredient per tree. During the first year none of the treated trees were damaged by termites, but 30 per cent of the controls died as a result of termite attack. Unfortunately longer term observations will not be possible in this case, as the trees have now been decimated by drought, accelerated by lack of plant nutrients and persistent defoliation by antelope. The trial has been of additional interest in apportioning the blame for continued failure of trees on this site.

This experiment was repeated in another difficult area—Lambwe Valley (Nyanza)—but using *E. saligna.* Over a period of eight months complete protection has again been noted, but the incidence of termite attack on the control trees this year has been low—only 10 per cent.

A third experiment has been laid out on Uuni Hill, where it is hoped that improved silvicultural methods, the use of fertilizer, and the prevention of game damage will produce results covering a longer period and also demonstrate that gums can survive there. The new objectives are twofold. Firstly we wish to find the mini-

mum dose of insecticide which will give protection, by the orthodox method already tried. Secondly it is hoped to find a quicker (and therefore cheaper) method of giving protection. Applying insecticide in the planting hole is perfectly effective if done efficiently, but slows the planting rate to $\frac{1}{2}$ or $\frac{1}{3}$. Mixing insecticide with the potting soil, or watering it on the plants in the nursery as practised elsewhere is a fine time-saver but ineffective where deep planting is necessary for the survival of the tree. Dipping and sheathing techniques now under trial are designed to give protection to the vulnerable stem above the original and below the new ground level.

HORTICULTURAL SECTION

W. B. May

Forestry Work

All forestry nursery experiments referred to in the report of the Silviculturist were carried out by the Horticulturist.

Thirty thousand *Eucalyptus saligna* were raised for estate planting, also several thousand Pines and Cypress.

Interspecific Grafts of Pines

A common vigorous stock that could be used for the rapid bulking up of superior vegetative material and for quarantine work, is clearly desirable. Both *Pinus radiata* and *P. patula* show promise. The following species have been successfully grafted on stocks of *P. radiata* and *P. patula*. Scions of *Pinus oocarpa, P. ponderosa, P. ayacahuite, P. Khasya, P. canariensis, P. montezumae, P. sabiniana* and *P. elliottii*.

From previous grafts made, subsequent growth of the scion is much greater on *Pinus radiata* stocks, than on *P. patula*. Compatibility and stock-scion influence is not being studied, since it is intended to use stocks of the same species as the scion for final seed orchard purposes.

The Horticulturist continued to do advisory work on nursery techniques and growing plants generally for the E.A. Departments of Forestry, and toured Tanganyika and parts of Kenya for this purpose.

Horticultural Work

The rapid propagation of Sisal hybrid No. 11648, was investigated in collaboration with E. C. Diekmanns of the Sisal Research Station, Mlingano, Tanganyika. The rhizomatous stems appear to be completely dominant. If, however, the rhizome is removed from the parent plant, and cut into single bud pieces, all the buds if planted, shortly commence to develop. The use of single rhizome buds greatly speeds the task of multiplication.

A certain amount of grafting work was carried out for the virologist. This included successful leaf petiole grafts of soyabean, using fairly mature leaves as scions, and young soyabean seedlings as stocks.

Vegetative propagation of various crops by means of cuttings received attention. The dippings of the cut basal end of single node tea cuttings enhanced callus formation, but did not promote rooting in a rooting mixture of high pH. Under mist spray treatment considerable leaching of nutrients from cocoa leaf cuttings occurs. The judicious use of foliar nutrient sprays is indicated.

Floral decorations for the East Africa High Commission stand at the Nairobi Royal Agricultural Society's show and High Commission Headquarter buildings, Nairobi, were provided by the Horticulturist.

THE EAST AFRICAN HERBARIUM

B. Verdcourt, G. L. Lucas, D. M. Napper, R. Polhill and G. R. Williams

Mr. Lucas took up his duties in East Africa in early November after spending a year at Kew. Apart from that a full complement of staff was present during the year.

In the period January to 30th November, 319 accessions of material were received totalling 7,623 specimens for determination, 1,474 named duplicates and 202 specimens received on loan for study. Routine naming of collections and supplying of information has as usual occupied most of the staff's time. A fair amount of time has also been spent helping various workers who, though prepared to name their own collections, need guidance on where to look. 8,800 specimens have been determined during the year apart from these casual identifications. 8,990 specimens have been sent to other institutions including named duplicates and specimens sent on loan for study.

The laying away of named mounted sheets is still a major problem. The remainder of the 30,000 specimens mentioned in last year's Report were laid away during the year but between 8,000 and 10,000 more specimens including about 2,000 grasses, are waiting to be laid away.

Research has again been rather limited. Miss Napper spent a good deal of time during a period of five months revising a booklet written by Mr. Harker of the Uganda Department of Veterinary Services on Uganda grasses. This involved a considerable amount of revision and a short visit to Entebbe. The manuscript is in the hands of the Government Printer. Mr. Lucas wrote accounts of the Fumariaceae and Papaveraceae for the Flora of Tropical East Africa, and also began work on the families Opiliaceae, Olacaceae, Icacinaceae and Octoknemataceae. Dr. Verdcourt wrote accounts of the families Pontederiaceae, Trimeniaceae and has almost completed the Basellaceae. Facilities for this type of work are few out here and even the simplest families have bibliographic problems only capable of solution in a large library. There is at present a delay of several years between the finishing of these accounts and their editing and final publication. A paper on certain Convolvulaceae from Central Africa was also completed and several papers on those of East Africa are also in the Press. An account of a very

interesting new species of *Erythrophysa* from the Ogaden has also been written and will be submitted for publication shortly. Mr. Polhill has been working on the huge genus *Solanum* and reduced our own material to a state of order.

Many visitors, some from overseas, have worked in the herbarium during the year. Dr. Greenway has worked in the herbarium several days a week throughout the year compiling a work of his own during the course of which he has helped by writing up numerous specimens.

As usual numerous new taxa have been described during the year from specimens originating from the East African Herbarium and yet further types have been found. The total number is now 1,129. Several hundred type photographs have been incorporated in the herbarium, mostly prints kindly run off by Kew. These are often of great value though in general, of course, much more difficult to interpret certainly than an actual specimen. It is to be regretted that numerous types have passed through our hands in the past and we have not been able to photograph them owing to lack of equipment. Dr. Verdcourt spent a very intensive week in November going through the E.A.T.R.O. herbarium now at Arusha. All types which could be recognized were removed amounting to well over a hundred but a complete list of what was obtained will take months to prepare. Since the herbarium had not been written up for some 15 years some attempt was made to bring the nomenclature up to date. Several thousand redeterminations were made.

Field work has as usual been limited. Proper full scale *safaris* are not feasible now that a large volume of work has to be coped with by a limited staff. Dr. Verdcourt and Mr. Polhill made short trips to the Bura Hills, Nyambeni Hills, also the Marimba and Meru Forests on Mount Kenya and collected several hundred numbers. At the end of December, 1959, Dr. Verdcourt made collections at Amboseli; he also collected near Kasulu and Kigoma whilst helping out Dr. Leakey by transporting a zoologist to the chimpanzee reserve north of Kigoma. Whilst helping an English film unit with tropical shots for a general film on the activities of Kew, a little collecting was carried out near Naivasha and Thika. General collecting was also carried out at Ol Orgasailie and other places on the Magadi road and in the Kedong Valley. A peculiar huge new species of *Adenia* was found in very dry country quite close to Kikuyu by Mr. Bogdan and a search was made for more material; good material of this plant (allied to *A. globosa*) was secured and sent to Kew. Mr. Polhill collected on the Aberdares, Kinangop, and Longonot, also at Kiboko, Komo Rock, etc.; he obtained several

plants on the Aberdares, including a *Senecio*, not represented in the herbarium. Miss Napper made collections in the Kitui and Kibwesi areas. Mr. Samuel Paulo was attached to a Carnegie Expedition and collected over a wide range of territory in East Africa. Mr. Jacobo Oteke was attached to a private *safari* of Mr. H. D. van Someren and collected on Marsabit and Kulal. The work of writing up field notes for these collections has yet to be done. None of the material collected by Mr. Newbould mentioned in last year's Report has been received.

MISCELLANEOUS SCIENTIFIC SERVICES

JOINT E.A.A.F.R.O./E.A.V.R.O. LIBRARY

L. D. Verdcourt, F. M. Searle, D. N. Lazarus

The work of the library progressed satisfactorily during 1960 and some of the planned long-term jobs were begun. These are, of necessity, finished very slowly due to the amount of routine work always on hand, but except for a period of two months, Mrs. Searle was working in the library, and some progress has been made.

In July the Librarian went to Entebbe to help the Forest Department organize their small but specialized library. This was at the request of the Chief Conservator for Uganda, who wanted a definite library system to be established so that the publications can be kept in good order with a minimum of supervision.

Valuable work was done by the bookbinding staff and the high standard and steady output maintained, even though the Head Bookbinder went on long leave and his assistant spent considerable periods in hospital. Many requests are now received to take on the binding of books for outside departments and institutions and it is gratifying to note that all these departments are eager to continue in the E.A.A.F.R.O. bookbinding scheme.

The number of requests for publications not available in our own library has increased considerably during the last year and more and more references are obtained on microfilm. This aspect of the library work involves a good deal of research and co-operation with other libraries in East Africa, but is an extremely valuable way of spending library time for the benefit of research staff who are reading up a new subject.

The Librarian has served on the East African Library Association committee throughout the year and their proposed scheme of co-operation between East African libraries gained official sanction, and came into operation on 1st June, 1960. Such schemes have been operating in the United Kingdom for many years and it is hoped that the East African scheme will result in increased efficiency and greater availability of scarce material.

EAST AFRICAN AGRICULTURAL AND FORESTRY JOURNAL

Editor: *J Glover*

The Journal continued to receive scientific papers from all over East Africa and even occasionally from outside this region when the subject matter warrants attention locally. As usual we have to squeeze a quart of material into a pint pot and some papers are severely pruned before publication. Otherwise, it would be impossible to cope with the material which is now coming forward from the various territorial departments.

The increase in the number of papers from the departmental research stations and their substations is particularly valuable in that many records which are often lost in archives are now printed and made available to others elsewhere. The overall saving in money which results is considerable because there is less tendency to repeat experiments in ignorance of what has been done in earlier years.

In July the title of the Journal was slightly altered. After 25 years as the East African Agricultural Journal the East African Agricultural and Fisheries Research Council, with the approval of the Secretary of State, decided that the new title should be the East African Agricultural and Forestry Journal. At the same time the Secretary of State kindly consented to carry part of the cost of the Journal out of the Colonial Development and Welfare Fund.

EAST AFRICA PLANT QUARANTINE STATION

F. M. L. Sheffield and P. J. Dickinson

The scientific supervision of the Quarantine Station is normally undertaken by E.A.A.F.R.O. staff. However, problems sometimes arise of which no one on the staff has specialist knowledge and it is then necessary to seek assistance elsewhere. We wish to thank all those specialists, particularly of the Kenya Department of Agriculture and Forestry who have so willingly helped us.

The Buildings

The only structural change made during the year has been the installation of additional heaters in some glasshouses necessitated by the introduction of consignments of cacao and of low altitude coffees.

Several changes have been made in procedure:

Nematodes

The most important change is in the handling of plants sent to us already rooted. Such material should have been rooted in a sterile medium but we find that this is not always done. In the past, after close examination, such plants were treated for any insects or fungi found and were then planted in a sterilized compost or rooting mixture. This treatment enabled any nematodes present to build up large populations which either killed the hosts or caused them to deteriorate. The nematodes were then found and the plants were destroyed.

Now, A. G. Whitehead is asked to examine upon receipt, all material likely to carry these parasites. He has already found upon imported material some forms not described in East Africa, as well as many indigenous here. However, it is equally important that no risk should be taken of introducing either new species or new strains of indigenous species.

Our present procedure is to plant rooted material in unsterilized soil compost to give it the greatest possible chance of survival. It is then propagated by cuttings or by grafting so that no underground parts of the imported plants are released. All remaining parts of the original plants are then destroyed and the soil in which they were grown is sterilized with disinfectant and heat before being discarded.

If stem or leaf eelworms were found, it would be necessary to destroy the material carrying them.

Open Quarantine of Sugar Cane

In the past, when new varieties were released from the quarantine glasshouses, they were sent to the Kawanda Research Station to be put into open quarantine and at the same time propagated for distribution in all three territories. Whilst expressing their gratitude to the Uganda Department of Agriculture for providing this service, the Kenya and Tanganyika Departments decided in the future each to undertake its own open quarantine. Stations for this purpose are being established at the Scott Agricultural Laboratories and at the Northern Regional Research Centre at Tengeru. Material released from Muguga will be divided equally between the three open quarantine stations.

Muguga Sugar Cane Collection

Two stools of each variety released from closed quarantine were grown in a small enclosure at E.A.A.F.R.O. This enclosure is now full and a further three acres of land granted to us has

been enclosed by a fence with a hedge planted outside it, and paths have been grassed down. The older, smaller compound will be retained for varieties that have not yet passed through open quarantine. Into the new compound will be put four stools of each variety released. Of the 81 varieties now held, 48 have already been replanted after receiving heat treatment. One stool of each variety will be replanted each year, so that mature setts should always be available. (In this compound will also be maintained a few other newly imported species, e.g. Sweet potatoes, Pelargonium.)

Issue of Cane Varieties

As well as our normal issues to the Departments of Agriculture, we were able to supply some 35 varieties from our collection direct to the Kilombero Valley Sugar Company and two to the Tanganyika Planting Company.

We have had an increased number of requests from territories outside East Africa and have been able to supply from our collection 17 varieties to Ethiopia, 7 to Ghana, 7 to Nigeria and 3 to the Sudan and expect to send away at least four further consignments early in 1961.

Species Held During 1960

The Station is being used for an increasing diversity of species. Handling of a species not previously introduced often necessitates experiments to find the best horticultural methods to employ under our glasshouse conditions, as well as perusal of the literature to discover what diseases the consignment might carry and the devising of tests for their presence.

Beans (Haricot)

(1) Seeds of three varieties of Haricot beans were imported by the Director of Agriculture, Tanganyika Territory, during 1959. As it was impossible to obtain from source a certificate of freedom from Bacterial Wilt (*Corynebacterium flascumfaciens*), they were grown in quarantine. The plants were found to be healthy and the resultant seed was harvested and released.

(2) A further consignment of four varieties of Haricot bean seed required for work in the Pathology Department of E.A.A.F.R.O. was received from the Crops Research Division, U.S.D.A. As these did not carry the necessary certification, they were grown in quarantine and when found to be healthy, the resultant seed was released. The varieties were Great Northern 1140, Pinto, Ramano, and Scout Pinto.

Cacao

At the request of the Director of Agriculture, Uganda, eight rooted cuttings of cacao, variety "Lafi 7" were received from the Royal Botanic Gardens, Kew, England. Owing to the poor condition of the plants on arrival only one has survived and this plant will be used for propagation by budding and grafting to healthy seedling stock. It will at the same time, be tested for the presence or otherwise of virus diseases by grafting to Amelonado seedlings. At a later date a top graft from a healthy Amelonado seedling will be placed on each established scion. This is the testing method recommended by W.A.C.R.I.

Coffee

(1) *Coffea excelsa.* Of selections 121/3, 490/51, Dybouwskii and Zaachinge java received in 1959 only one plant of variety 490/51 survived and cuttings will be released, when ready, to Jacaranda Coffee Research Station, Kenya.

(2) *Coffea robusta.* Selections and hybrids were received from the Laboratorium Tropische, Landbouwplantenteelt, Holland, on behalf of Jacaranda Coffee Research Station. The consignment of 80 plants included ten rooted cuttings of each of the following selections: *C. robusta* (B.P.39 and B.P.42), *C. robusta* ex Java (S.A.24, S.A. 34 and S.A.158) and Cramer's *C. robusta* Uganda X *C. congensis* (Con.161, Con.203 and Con.218). These plants were all established in unsterilized soil and therefore only vegetative material for propagation will be released. The first cuttings of the three hybrid selections have already been released to Jacaranda Coffee Research Station, Kenya. Cuttings of *robusta* selections, S.A.24 and S.A.34 will be issued in the near future.

It has been agreed that cuttings from all plants found to be free from disease shall be offered to the Departments of Agriculture of Tanganyika and Uganda. To produce the requisite amount of propagating material, it will be necessary to retain the plants for a considerable period.

Liquorice (Glycyrrhiza glabra)

A number of root-cuttings of a high yielding strain of this plant were received from the Department of Agriculture, Cyprus, for the Director of Agriculture, Kenya. Four plants are now established but they are growing very slowly and it has not yet been possible to complete the tests for the presence of virus disease.

Pelargonium

All the plants of an importation made by a grower of a high oil-yielding Pelargonium variety from Réunion in 1959 were tested for the presence of latent viruses by grafting to Pelargonium seedlings and all were found to be healthy. The plants were propagated and 125 rooted cuttings were released to the grower who kindly presented to us four plants for propagation and distribution to the Departments of Agriculture of Kenya and Tanganyika Territory. Three plants have been issued to the Northern Regional Research Centre at Tengeru, T.T. and further plants will soon be available for release to the Scott Laboratory, Kenya. Four plants will also be established in the E.A.P.Q.S. Collection Plot.

Pineapples for Fibre (Ananas bracteatus)

Ten suckers were imported by the Director of Agriculture, Kenya, from the Botanical Gardens, Singapore. Tests to indicator plants showed them to be free from Tomato spotted wilt virus. Five plants were released to the Horticultural Section of the Department of Agriculture, Kenya, and one will be held in the E.A.P.Q.S. Collection of Plants released from quarantine.

Soya Bean

Seed of two varieties of Soya bean, "Hernon Local" and "R 184", was received from the Department of Agriculture, Nyasaland, on behalf of the Director of Agriculture, Kenya, without the necessary certification from source. Plants are being grown in quarantine and if they prove to be healthy the resultant seed will be released.

Sugar Cane

We were able to release only four varieties—

Co.991, Q 67, Q 70, and Trojan

from closed to open quarantine during 1960.

This was due partly to our having to destroy the following 13 varieties received in 1959—

CI.41/223, 47/83, 47/143
C.P. 31/511, 48/103, 50/28, 52/68, 52/107, 53/18*
Co.785*
POJ 3067
PR 980.

~~With the exception of CP 53/18 which was destroyed, these are now all held in closed quarantine~~.

* Second or third importation of this variety made through Muguga quarantine, the previous consignments having been found to be diseased.

Some of these were probably infected with virus disease and others with bacterial disease. We were also obliged to delay the release of three varieties that had been in contact with Co.785.

Varieties imported during 1959 and still held in closed quarantine are:—

B.4744
B.O.10*, 11*
Co.440, 680*, 684*
M 134/32
PR 809
Ragnar.

Through the generosity of the U.S.D.A. Agricultural Research Service and the Directors of the Laboratorium Tropiche, Landbouwplantenteelt, Holland, the West Indian Central Sugarcane Breeding Station and the Agricultural Experiment Station, Puerto Rico, the Director of E.A.A.F.R.O. was able to import the following varieties and hybrids during 1960.

1. *Sugar Cane*
   B.52298
   C.P.53/18*
   H 32/1063
   POJ 2722, 2753, 2801, 2822, 3142, 3150
   PR 975, 980*, 1007, 1013.

2. *Sugar Cane—Sorghum Hybrids*
   US 56-37-9, US 56-38-13
   US 57-229-1, US 57-230-6, US 57-230-7, US 57-230-10, US 57-231-4, US 57-232-3
   US 59-80-6, US 59-83-1, US 59-198-2.

Experimental Work

Cacao. To enable us to test Cacao plants successfully for virus diseases several grafting and budding techniques are being tried on seedlings raised in quarantine glasshouses. The seedlings are now six to seven months old and at a stage suitable for budding. Six methods of budding are being tried as well as three methods of grafting. Success has already been obtained with top grafts and two budding methods.

* Second or third importation of this variety made through Muguga quarantine, the previous consignments having been found to be diseased. With the exception of CP 53/18 which was destroyed, these are now all held in closed quarantine.

Coffee. Difficulties had been experienced in growing coffee received into quarantine, and after discussion with Mr. Hangar of Jacaranda Coffee Research Station, it was decided to try various potting mixtures, both sterilized and unsterilized.

The standard Muguga mix was used as a basis for experiment. The soil ingredient was obtained from the quarantine estate and both coffee hulls and vermiculite in varying proportions were used as substitutes for peat and clay in the Muguga mix. One mixture was made with a very small proportion of soil to the amount of gravel and coffee hulls. In all, five mixtures were used, and each was divided into four sections: sterilized, with and without fertilizer and unsterilized, with and without fertilizer.

Seedlings have been in these mixtures for some six months. In those four mixtures that contain a large proportion of Muguga soil, sterilizing or the addition of fertilizer has a stunting effect on young seedlings. The experiment is still in progress and it is hoped that at a later date both plants and soil will be analysed.

Sugar Cane. Some plants were received from Kawanda Research Station where they had shown white streaks on the young leaves after the setts had been hot-water treated for Ratoon stunting disease. It was suspected that the treatment might be responsible. To test this hypothesis both excessively long periods of treatment and excessive doses of mercurial compounds were tried. We were not, however, able to reproduce the symptoms. When grown on, the original plants either died or recovered completely.

Nematodes. To ensure that the method used in the sterilization of the ingredients used in the soil mixture was effective against nematodes, pot experiments were carried out using soil that was freshly sterilized and soil that had been sterilized for six months and then stored under cover.

Twenty tomato and 20 tobacco seedlings were pricked out into each mixture and were grown until the pots were completely full of roots. A. G. Whitehead then made a careful examination of the roots but could find no evidence of the presence of parasitic nematodes. It was concluded that the technique used in soil sterilization was adequate for the control of nematodes.

Plant Import Control

P. J. Dickinson continued to act as Secretary and F. M. L. Sheffield to serve on the East African Standing Technical Committee for Plant Import and Export to the work of which reference has been made on page 64.

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